TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

1933

SIXTY-THIRD ANNUAL MEETING
COLUMBUS, OHIO
SEPTEMBER 18, 19 and 20, 1933

TRANSACTIONS

OF THE

American Fisheries Society

SIXTY-THIRD ANNUAL MEETING
COLUMBUS, OHIO
September 18, 19 and 20, 1933

Published Annually by the Society

1933

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

OFFICERS FOR 1932-1933

President—H. S. DAVIS, Washington, D. C.
Vice-President—FRED A. WESTERMAN, Lansing, Mich.
Secretary-Treasurer—SETH GORDON, Washington, D. C.
Librarian—EBEN W. COBB, Hartford, Conn.

VICE-PRESIDENTS OF DIVISIONS

Fish Culture—C. R. BULLER, Pleasant Mount, Pa.
Aquatic Biology and Physics—EDWARD L. WICKLIFF, Columbus, Ohio
Commercial Fishing—JOHN VAN OOSTEN, Ann Arbor, Mich.
Protection and Legislation—GUY AMSLER, Little Rock, Ark.
Angling—SAMUEL B. LOCKE, Chicago, Ill.

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Aquatic Biology and Physics—ELMER HIGGINS, Washington, D. C.
Commercial Fishing—W. A. CLEMENS, Nanaimo, B. C., Can.
Protection and Legislation—GUY AMSLER, Little Rock, Ark.
Angling—W. J. TUCKER, Austin, Texas

***For street addresses see membership list.**

COMMITTEES, 1933-1934

EXECUTIVE COMMITTEE

FRED J. FOSTER, *Chairman*........Salt Lake City, Utah
I. T. QUINN........Montgomery, Ala.
JOHN L. FARLEY........San Francisco, Calif.
EUGENE W. SURBER........Leetown, W. Va.
JAMES BROWN........Montpelier, Vt.
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WILLIAM C. ADAMS........Albany, N. Y.
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HARRY B. HAWES........Washington, D. C.
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WILLIAM J. K. HARKNESS........Toronto, Can.
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C. C. REGAN........Covington, Ky.

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WILLIAM J. K. HARKNESS........Toronto, Can.
JOHN O. SNYDER........Stanford University, Calif.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.

***A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.**

35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W.Va.
36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George C. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Canada
61.	James A. Rodd	1931-1932	Hot Springs, Arkansas
62.	H. S. Davis	1932-1933	Baltimore, Md.
63.	Fred A. Westerman	1933-1934	Columbus, Ohio

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TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

AT

COLUMBUS, OHIO,

September 18, 19 and 20, 1933

The sixty-third annual meeting of the American Fisheries Society was held at the Deshler-Wallick Hotel, Columbus, Ohio, September 18, 19, and 20, 1933, the President of the Society, Dr. H. S. Davis, of Washington, D. C., presiding.

REGISTERED ATTENDANCE

The following is the list of registered members, delegates and guests in attendance:

Adams, William C., Albany, N. Y.
Allin, Curtis S., Frankfort, Ky.
Amsler, Guy, Little Rock, Ark.
Anderson, Wendall, Woodruff, Wis.
Bangham, R. B., Wooster, Ohio
Bell, Hon. Frank T., Washington, D. C.
Berlin, G. C., Columbus, Ohio
Brown, James, Montpelier, Vt.
Brummell, L. L., Columbus, Ohio
Buford, W. C., Jefferson City, Mo.
Chute, W. H., Chicago, Ill.
Cobb, E. W., Hartford, Conn.
Cook, A. B., Lansing, Mich.
Cook, R. E., Columbus, Ohio
Corcoran, J. P., Baltimore, Md.
Cowden, S. M., Albany, N. Y.
Culler, C. F., La Crosse, Wis.
Davis, H. S., Washington, D. C.
Davis, Stanley, Columbus, Ohio
Deason, H. J., Ann Arbor, Mich.
Deibler, O. M., Harrisburg, Pa.
Deuel, Charles, Canton, N. Y.
Duncan, E. C., Columbus, Ohio
Earle, Swepson, Baltimore, Md.
Embody, G. C., Ithaca, N. Y.
Eschmeyer, R. W., Ann Arbor, Mich.
Farley, John L., San Fraancisco, Cal.
Farr, Anthony, Marysville, Ohio
Franks, Rosco, Cleveland, Ohio
Field, Geo. Wilton, Washington, D. C.
Folger, A. T., Jr., Chicago, Ill.
Follett, Richard E., Detroit, Mich.
Goodman, Joseph C., Columbus, Ohio
Gordon, Seth, Washington, D. C.
Greeley, John R., Ann Arbor, Mich.
Greene, C. W., Albany, N. Y.
Greer, R. L., Washington, D. C.
Grim, D. N., Glen Eyre, Pa.
Hankinson, T. L., Ypsilanti, Mich.
Harkness, W. J. R., Toronto, Ont.
Harner, Ernest, Xenia, Ohio
Hawes, Harry B., Washington, D. C.
Hayford, Charles O., Hackettstown, N. J.
Herndon, G. B., Jefferson City, Mo.
Heyward, A. C., Columbia, S. C.
Higgins, Elmer, Washington, D. C.
Hills, C., Wild Rose, Wis.
Hogan, Joe, Lonoke, Ark.
Hogarth, Geo. R., Lansing, Mich.
Howley, Thomas, New York, N. Y.
Hubbs, Carl L., Ann Arbor, Mich.
Huhn, H. C., Bristol, Conn.
Hunter, R. M., Nicholasville, Ky.
James, Herman D., Somerville, Ga.
Juday, C., Madison, Wis.
Kingsbury, O. R., South Otselic, N. Y.
Langford, R. R., Toronto, Ont.
Langlois, T. H., Columbus, Ohio
Lauffer, Walter M., Mt. Gilead, Ohio
Lay, Charles, Sandusky, Ohio
Leach, B. K., St. Louis, Mo.
LeCompte, E. Lee, Baltimore, Md.
Lincoln, Guy, Oden, Mich.
Locke, S. B., Chicago, Ill.
McCurry, J. C., Columbus, Ohio
Marelli, D. Carlos, Buenos Aires, Argentine
Markus, Henry C., Rochester, N. Y.
Miller, Ray, Zanesville, Ohio
Needham, J. G., Ithaca, N. Y.
O'Neal, Lloyd A., Northville, Mich.
Osburn, Raymond C., Columbus, Ohio
Oughton, J. P., Toronto, Ont.
Pate, V. S. L., Ithaca, N. Y.
Powell, Albert, Lewistown, Md.
Price, John W., Columbus, Ohio
Regan, C. C., Covington, Ky.
Ripley, Ozark, Chattanooga, Tenn.
Rodd, J. A., Ottawa, Ont.
Roth, Conrad, Portsmouth, Ohio
Russ, Howard C., Mumford, N. Y.
Shetter, James S., Ann Arbor, Mich.
Shoemaker, Carl D., Washington, D. C.
Shuttee, Harry C., Kansas City, Mo.
Smith, Osgood, Ithaca, N. Y.
Stack, George F., Cresco, Pa.
Surber, T., St. Paul, Minn.

Tarzwell, Clarence, Ann Arbor, Mich.
Terrell, Clyde, Oshkosh, Wis.
Thomas, Carey, Tallahassee, Fla.
Thomas, Edward, Columbus, Ohio
Tidd, W. M., Columbus, Ohio
Trautman, M. B., Columbus, Ohio
Tresselt, Frederick, Thurmont, Md.
Trout, Wayne, Columbus, Ohio
Tucker, George, Gilmer, Tex.
Tucker, Wm. J., Austin, Tex.
Tunison, A. V., Cortland, N. Y.
Van Oosten, John, Ann Arbor, Mich.
Venard, Carl, Columbus, Ohio
Walker, Charles F., Columbus, Ohio
Warner, David C., Columbus, Ohio
Weaver, Percy, Madison, Wis.
Webster, B. O., Madison, Wis.
Westerman, Fred, Lansing, Mich.
Wickliff, E. L., Columbus, Ohio
Wiebe, A. H., Austin, Tex.
Wolf, Louis E., Ithaca, N. Y.
Young, E. C., Ottawa, Ont.
Zalsman, Phil G., Grayling, Mich.

BUSINESS SESSIONS

The meeting was called to order by President Herbert S. Davis at 10:00 A. M. Monday, September 18, 1933.

Addresses of welcome were delivered by the Secretary to Mayor Henry W. Worley of Columbus, and by William H. Reinhart, Conservation Commissioner of Ohio, to which the President responded at some length.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

For the year 1932-33

SETH GORDON

The American Fisheries Society has held its own exceptionally well during the past fiscal year, ending June 30, 1933, despite economic conditions which made it very difficult for all organizations of this character.

While the net balance in the treasury at the end of the fiscal year is very small, it must be borne in mind that, due to the change made in the fiscal year at the last annual meeting to agree with the membership year, this report covers a period of but ten months.

During the ten months mentioned, fifty-eight members were dropped from the rolls for non-payment of dues, and only twelve members resigned. The loss through death was ten. Seventy-three new members were enrolled from September 1, 1932 to June 30, 1933, making the net loss just seven members. During the previous year our loss was eighty-five.

A special letter was sent to all members in arrears for three years, calling their attention to the provisions of the By-laws and urging them to pay up their back dues. Those not responding to this appeal were then dropped from the rolls.

Your Secretary has endeavored to build up the membership, but notwithstanding the aid of others who cooperated we were not quite able to hold our own.

There are two potential fields which have not produced anything like the response the work of the Society merits. Every state and every province should hold official membership in the Society, but at the present time this class of membership is held by only twenty-one states.

While I realize the difficulties encountered by these public agencies in expending funds for such purposes, I am confident the number of such memberships could be greatly increased if a concerted effort were made to that end. Some states not only hold an official state membership, but they also pay the annual dues of their various hatchery superintendents.

Where the states and provinces cannot legally pay for such memberships out of their funds, they can at least urge all their superintendents of hatcheries to become members in order that they may be eligible to attend meetings and to present papers, and so that they may each receive the Transactions of the Society for use as reference volumes. Only a few state and provincial departments have cooperated actively in this manner, and your Secretary is hopeful that during the coming year a special effort may be made to that end.

Some time ago all the superintendents and other important workers in the U. S. Bureau of Fisheries were invited into membership, but the response was not very encouraging. We hope for better results from this group now

since the worst is apparently over in connection with the federal government's slashing under the economy program and the men who are left know better where they stand.

I want to repeat my appeal of last year to the state and provincial hatchery superintendents. Recently I asked all the departments for lists of their superintendents in order that they might be invited to this meeting, also in order that they might be urged to join the Society.

State and provincial officials are urged to give us assistance in this matter right now. And they also can tell us about commercial fishermen and operators of commercial hatcheries in their states who should belong to the Society; or, better still, obtain enough blanks from the Secretary and write direct to those who should become members.

Another large group of workers, and a very important one, too, who should become actively associated with the Society are the scientific leaders at our various educational institutions throughout both the United States and Canada. We already have many of these on the rolls of the Society, but not nearly enough of them. A recent invitation to hydrobiologists has brought some response, but here is a fertile field for members of the Society.

We are rather proud of the Transactions of the 1932 meeting. The comments on those Transactions have all been most favorable. The printer who did the work gave this volume his personal attention; he was much perturbed when it developed that one of his employes had upset part of one of the small tabular statements.

During the year your Secretary had occasion to represent the Society on a number of occasions in Washington in connection with matters of considerable concern to the fisheries workers of the United States, as well as to those interested in both angling and commercial fishing.

I want to take this opportunity to thank the members of the Society for their fine cooperation during the past year, and to express the hope that when we meet next year we can report a material increase in membership.

The financial transactions of the Society for the year ending June 30, 1933, were as follows:

TREASURER'S REPORT

September 1, 1932 to June 30, 1933

General Fund

Receipts		
Balance on hand September 1, 1932		$1,641.88
Annual Dues:		
Individuals and Libraries		
For the year 1928	$3.00	
1929	3.00	
1930	12.00	
1931-1932	72.00	
1932-1933	521.80	
1933-1934	315.00	926.80

Clubs and Dealers		
For the year 1930	5.00	
1931-1932	10.00	
1932-1933	65.00	
1933-1934	50.00	130.00
State Memberships		
For the year 1932-1933	30.00	30.00
Life Membership		50.00
Sale of Transactions		220.76
Sale of Separates:		
1931 Transactions	56.63	
1932 Transactions	25.25	81.88
Exchange on checks		1.42
Transferred from Permanent Fund*		359.25
Total Receipts		$3,441.99
DISBURSEMENTS		
Stationery and Printing		$50.38
Postage		205.98
Exchange on checks		16.91
Tax on checks		.70
Office supplies		2.52
Traveling expenses		13.78
Telephone		6.85
Telegraph		7.14
Clerical and secretarial expenses		
Seth Gordon	$100.00	
American Game Association	100.00	
E. M. Quee	150.00	
Stenographic services re Black Bass Legislation	13.33	363.33
Investments**		923.09
Express		12.36
Miscellaneous—photographs		3.00
Insurance		19.50
Premium on Treasurer's bond		5.00
Transactions, 1932, Vol. 62		
Indexing	60.36	
Printing	1,118.35	
Separates	9.50	1,188.21
Reporting 1932 Proceedings		225.00
Separates, 1931 Transactions		69.93
Checks returned—Bank Holiday		6.00
Permanent Fund—(itemized in Permanent Fund Report)		200.00
Total Disbursements		$3,319.68
Receipts General Fund	$3,441.99	
Disbursements General Fund	3,319.68	
Balance on hand July 1, 1933		$122.31

*To reimburse General Fund for amount transferred—$159.25 to add to permanent investments of the Society, and $200 to cover abstracting services for 1932 volume.

**Authorized at 1932 Meeting.

Permanent Fund

Receipts

Balance on hand September 1, 1932		$164.49
Interest on Savings Account	$5.62	
Interest on Title Guarantee & Trust Co. Certificates and N. Y. Title & Mortgage Co. Certificates	235.22	
Dividends on Commonwealth Southern, pfd.	45.00	285.84
		$450.33

Disbursements

Abstracting for 1932 Transactions	200.00	
Repayment of loan from General Fund	159.25	$359.25
Balance on hand July 1, 1933		$91.08
Par value of Certificates Title Guarantee & Trust Co.		4,000.00
Par value of 10 shares Commonwealth & Southern pfd. @ $100 each		1,000.00
Par value of Certificates N. Y. Title & Mortgage Co.		1,000.00
		$6,091.08*

*The market value of Certificates of Guarantee and Trust Co. and N. Y. Title and Mortgage Co. during the past year has been considerably below par, but since there is no open market there is no established cash value available. The cash value of the 10 shares of Commonwealth & Southern pfd., par value $100, as of June 30, 1933, was $522.50.

For the further information of the members of the Society, I have prepared a brief supplemental report covering the period from July 1 to September 11, which shows that during that period we had receipts of $775.58, and expenditures of $320.74, with a balance on hand in the general treasury of $577.15. During this same period we also received 17 individual applications and 2 state applications for membership.

The report of the Secretary-Treasurer was received and referred to the Auditing Committee. Upon the approval of the committee it was later accepted as submitted.

REPORT OF LIBRARIAN

Eben W. Cobb

During the last year the Secretary has very kindly taken over a part of the reports which were held for sale and when orders were received for one of these, or a new membership has come in, the volume has been forwarded from Washington or from my office, according as to where the order was received.

The work has been mostly seeing that all volumes were properly cared for. At present all except the small number in Washington are stored in the vaults in the basement of the State Office Building in Hartford, Connecticut, where steel bookcases are provided by the state.

(See back cover for information concerning transactions.)

REPORTS OF STANDING COMMITTEES

REPORT OF MEETING OF THE COUNCIL OF THE SOCIETY

The Council of the American Fisheries Society met at the Hotel Deshler-Wallick, Columbus, Ohio, at 8 P. M., on September 17, 1933, those present being H. S. Davis, President; Fred A. Westerman, Vice-President; Seth Gordon, Secretary-Treasurer; Eben W. Cobb, Librarian; and Messrs. Edward L. Wickliff, John Van Oosten, and Guy Amsler, Vice-Presidents of Divisions.

William H. Reinhart, Chairman of the Local Committee on Arrangements, and Messrs. Henry Baldwin Ward and E. Lee LeCompte, former presidents of the Society, were present by invitation.

The minutes of the 1932 Council meeting were reviewed, as was the progress of the Society during the past year.

The Librarian reported that the library of the Society and the stock of volumes have been insured, that all mixed sets of Transactions have been assorted properly, and that the entire library and stock of Transactions has been stored in a fireproof vault in the State Capitol at Hartford, Connecticut.

The President reported that the action on Doctor Bajkov's recommendation of last year concerning cooperative arctic investigation must be further deferred.

The President informed the Council concerning the arrangements of the past year relative to abstracts of foreign fisheries literature, which cost the Society $200 plus printing. After discussion it was moved by Mr. Westerman, seconded by Mr. Cobb, and agreed to, that Messrs. H. S. Davis and J. A. Rodd as a committee of two be authorized to work out a plan to abstract such foreign fisheries literature as may be deemed of value to the members of the Society, and that this committee be authorized to expend not to exceed $100 of the Permanent Fund income during the coming year.

President Davis called attention to his invitation to hydrobiologists to meet with the Society this year, with the possibility that those interested in this special field may decide to organize a special organization of their own.

After some discussion it was moved by Mr. Wickliff, seconded by Mr. Van Oosten, and agreed to that the President extend an invitation to these gentlemen to become associated with the Society and that they help to develop the work of the Division of Aquatic Biology and Physics. (At a later conference of hydrobiologists this plan was accepted.)

Upon motion approved, the Secretary was authorized to transfer certain members who have paid dues for twenty-five or more years to the list of life members if they make formal application for such transfer.

Upon motion made and agreed to the Secretary was authorized to accept a reduction in rate of interest on certain of the Society's permanent investments if such action is deemed desirable at this time, or to take such other steps as may be necessary to protect the Society's investment.

After some discussion, a standing Committee on Scientific Names of Fishes, authorized by the 1932 meeting of the Society, was selected as fol-

lows: Dr. Carl L. Hubbs, Michigan, Chairman; E. L. Wickliff, Ohio; S. F. Hildebrand, District of Columbia; Prof. Wm. J. K. Harkness, Province of Ontario; and Dr. John O. Snyder, California.

The desirability of making back volumes of the Society's Transactions available to members and libararies at a lower price than the cost of an annual membership was considered at length, and upon motion of Mr. Van Oosten, seconded by Mr. Westerman, and agreed to, it was decided to sell all volumes more than five years old (actually in print) at $1.00 each, the Librarian to preserve two copies of each volume for the permanent library, and to immediately set aside ten more sets as nearly complete as possible for sale only as complete units. (Volumes not over five years old cost $3.00 each.)

Doctor Ward discussed various matters for the welfare of the Society, and urged that the Society continue its effort to have pollution eliminated from our public waters.

There being no further business, the meeting adjourned at 12:30 A. M.

SETH GORDON, *Secretary.*

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

J. A. RODD, *Chairman*

The American Fisheries Society as a society really has no direct foreign relations, unless we regard as foreign the membership in England, Scotland, Japan, Italy, Russia, Sweden, Roumania, Australia, the Straits Settlements, the Argentine and Uruguay. My report is necessarily very largely a repetition of the excellent report submitted at Baltimore last year.

Migratory fish, like migratory birds and animals, do not recognize national boundaries and can be perpetuated and conserved properly for present and future generations only by international agreement.

A great deal has been accomplished in this way by the United States and Canada for the mutual benefit of both countries, and there is no fishery question of major importance in boundary or contiguous waters that has not been or is not the subject of an international investigation or on which agreement has not been reached.

An outstanding instance of international achievement is the Pelagic Sealing Treaty of July 7th, 1911, entered into by Canada, the United States, Japan and Russia. As a result of this treaty, the fur seal herd that breeds on the Pribiloff Islands has increased from a state of almost commercial extinction in 1910 to over 1,000,000 animals, and permits of a safe annual take of 50,000 skins of surplus males.

A treaty was ratified by the United States and Canada on October 21st, 1924, to preserve the valuable halibut fishery of the easterly portion of the North Pacific ocean, which had declined to an alarming degree. An International Fishery Commission was established under this treaty to investigate and make recommendations to the two countries for such concurrent action as might be necessary in the interests of this fishery. Tedious delays

which sometimes occur in matters of this nature were guarded against by the revised Treaty of May 9th, 1931, whereby regulations necessary for the perpetuation and the development of this fishery may now be made by the International Fishery Commission, with the approval of the President of the United States and the Governor-General of Canada.

The Fraser River-Puget Sound sockeye salmon fishery has been the subject of much international investigation and negotiations between Canada and the United States. The recommendations for the rehabilitation of this valuable fishery, made by the International Commission that was appointed under the Convention of May 26th, 1930, have been ratified by Canada to become effective when similar action is taken by the United States.

The International Pacific Salmon Federation, which is composed of representatives of the Fisheries Departments of the Federal Governments of the United States and of Canada, of each of the States of California, Oregon, Washington, the Province of British Columbia, and the territory of Alaska, cooperate in and correlate the results of investigations in regard to Pacific salmon of the authorities represented, and prevent unprofitable duplication of effort.

The Great Lakes Conservation Council, consisting of representatives from the Bureau of Fisheries, the Province of Ontario and from each of the States interested in the fisheries of the Great Lakes, has held a series of conferences to consider and to adopt conservation measures to counteract the decline and to restore these valuable fisheries to their former productiveness.

The Lake Erie Advisory Committee, an offspring of the Council, on December 2nd, 1932, agreed to uniform regulations for Lake Erie, which have since been ratified by a majority at least of the Provincial and State governments concerned.

Missisquoi Bay, particularly that portion of it that lies in the province of Quebec, is one of the important spawning grounds for the pike-perch or dore of Lake Champlain. The pike-perch is regarded as a game fish in the states of Vermont and New York, but is not so regarded in Quebec waters. This fishery, in its many aspects, is now being investigated by a joint international fact-finding commission appointed by the United States and Canada.

The possible effect of proposed power dams at Passamaquoddy Bay that might prove disastrous to the fisheries of that region is being investigated by an international commission appointed by the two countries concerned. The reports of the experts engaged in this investigation are expected in the near future.

The North American Council on Fisheries Investigations, with representatives from Canada, the United States, Newfoundland and France, was established in 1920. It correlates the results of fisheries investigations in the western North Atlantic ocean and makes them available to the countries concerned. The coordination and cooperation effected in this manner conserve the funds from all sources that may be available for these investiga-

tions by avoiding unnecessary duplication of effort. The Council met at St. Andrews, New Brunswick, on September 13th and 14th, 1933.

California is, at present, quite apprehensive in regard to the possible effect on her valuable sardine (pilchard) fishery, of floating reduction plants that operate outside the three-mile limit in waters beyond the jurisdiction of that State.

Questions of a local or national character assume a national aspect with the elimination of time and distance by speedy modern methods of transportation, and the American Fisheries Society would be well advised to continue to support the solving of such problems as they arise, by international investigation and agreement.

Discussion

MR. FOLLETT: There are some of us here who are familiar with that treaty that was worked on so long by two splendid men, Dr. David Starr Jordan and Professor Edward E. Prince, of Ottawa. We in Michigan are responsible for the defeat of that report; it was done by one of our United States Senators who had a personal friend engaged in the herring business in the Saginaw Bay.

May I mention one other thing while I am on my feet? There is a duty of $2.00 per hundred on fish shipped into the United States from Canada. I consider it unreasonable and unfair and unfriendly. I shipped a salmon from Gaspé last year that weighed eight pounds; I caught it the last day of the season and sent it to a friend of mine in Detroit, and the express and duty on it amounted to over $5.00. I sent two salmon from Port Daniel last July, weighing ten pounds apiece, and the express and duty on them amounted to $5.94. About a month ago I sent a large cod fish, weighing thirty-five pounds; I paid thirty-five cents for the cod fish and the charge on it when it got to this side amounted to $4.94. I think some action should be taken to have that duty reduced or abolished.

DR. MURPHY: A friend of mine in Detroit, said he paid more than $25.00 in duty alone on salmon that he sent from his own river to his friends. Here is where the hardship comes in: Tons of whitefish, pike-perch and lake trout from the Canadian lakes are sent in during the winter months; they are caught late in the fall on the spawning beds, many of them being brought in by dog teams to the railroad stations in a frozen or half frozen state. I do not consider they are in good condition when they get to Detroit or Chicago, but the poor people have to pay two cents a pound duty on every one of these fish. Many tons of fresh water fishes are consumed during the latter part of the winter, especially in the lenten season, and I think some relief should be afforded in respect of this duty.

THE PRESIDENT: I do not know whether or not that is a matter which falls within the province of the Foreign Relations Committee. Possibly Mr. Follett might take his troubles to the Resolutions Committee; they might help him out.

MR. FOLLETT: I was in doubt whether it was a matter to be brought up before this Society, but it does seem to arise out of Mr. Rodd's remarks on international relations.

MR. RODD: How long has that duty been in effect?

MR. FOLLETT: For a great many years—I should say two decades. Possibly it has not been in force as long as that, but many a man in the Gaspé region has been ruined by it. Many men who sent mackerel to New York would get no return at all by the time the express and duty were paid. Sometimes they would get what the express amounted to, and sometimes what the duty and express amounted to, but seldom did they get a profit.

MR. RODD: I was referring to the occasional salmon you might send down; has there always been a duty on such fish?

MR. FOLLETT: Always. When you kill moose, deer or caribou in the province of Quebec your license permits you to send your game home, but no provision is made for the salmon fisherman or the trout fisherman.

COMMITTEE ON THE SCIENTIFIC NAMES OF FISHES

THE SECRETARY: The name of the committee selected by the Council, at the request of the Society last year, known as the *Committee on the Scientific Names of Fishes,* is as follows: Carl L. Hubbs, University of Michigan, Chairman; E. L. Wickliff, Ohio Division of Conservation; S. F. Hildebrand, Bureau of Fisheries, Washington, D. C.; W. J. K. Harkness, University of Toronto, and John O. Snyder, California Game and Fish Commission.

If any of you gentlemen have any problems to take up with reference to the names of fishes, get in touch with one of these members.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE VICE-PRESIDENT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

E. L. WICKLIFF

During the summer forty-seven letters were sent out to investigators requesting information on aquatic biology and physics; thirty-two replies were received. The following is a summary of the work completed during 1932 or 1933, or under way at the present time. Results of the investigations were divided into two subdivisions. First, fisheries research reported elsewhere; second, aquatic biology and physics summarized in this paper.

I. BRITISH COLUMBIA—DR. WILBERT A. CLEMENS, Pacific Biological Station, Nanaimo, and co-workers:

1. A mortality of 95 to 99 per cent in sockeye salmon in fresh water during the egg, fry and fingerling stages. Causes for the high mortality and methods to overcome some of the difficulties are being determined.

2. To determine the extent of natural and artificial propagation of Kamloops trout necessary to maintain a high level of productivity from the angler's viewpoint.
3. Treating brown trout fry with a salt bath (2 ounces of Sodium Chloride per gallon of water for 15 to 30 minutes) after removing adipose fin for migration studies, reduces the mortality from 8 per cent (untreated fish) to 2 per cent.
4. Examination of fish meals for the possible presence of a factor toxic to salmon fry.
5. Furunculosis and protozoan disease studies.
6. Morphological studies show little evidence of races of trout because of their modification by temperature and other factors.
7. Food of trout as it affects the rate of growth, reproduction and breeding habits.
8. Food of predaceous fish of Cultus Lake in relation to survival of young sockeye salmon.

II. CALIFORNIA—Dr. J. O. Snyder, Bureau of Fish Culture, San Francisco. *Salmon studies:*

—W. L. Scofield, State Fisheries Laboratory, Terminal Island.

"Our research program is concerned chiefly with studies of fluctuations in the supply of the more important commercial species of marine fishes in this State. This includes both natural fluctuations in abundance and changes caused by man's fishing. This means detecting signs of a lessening in the supply, especially determining the presence of over-utilization and suggesting remedial measures for legislation. Remedies involve knowledge of life history so that we are carrying on life history work in addition to population studies.

"The most important project is a study of the California sardine, started some fourteen years ago. Most of the research staff contributes to this study, either as special studies or assisting in carrying on the routine work of sampling the catch each season at the various fishing ports. A study of the tuna fishery is also cooperative with special assignments to different staff members. A study of our mackerel fishery has engaged the efforts of two staff members.

"*Sardines:* Results from past work with new contributions have been summarized recently in reports not yet published. Conclusions as to migrations have been drawn by H. C. Godsil. Godsil has also cleared up much of our confusion as to local populations in sardines. Frances N. Clark has also summarized, in reports not yet published, her own work and that of others as to movements of sardines along our coast, age at sexual maturity and growth rate. Frances N. Clark has also reported on the manner of sardine spawning, based on studies of ova samples. E. C. Scofield has reported the areas and extent of spawning by means of quantitative tow hauls for eggs and larval stages. Frances N. Clark has reported on time spent by fishermen in scouting for sardine schools as a measure of changes in abundance. The sizes of fish caught by different types of nets and in different localities have been reported by J. B. Phillips and G. H. Clark, who in addition have made a study of the relative destructiveness of various sardine fishing gear.

"*Tuna:* Aside from early reports, no important studies have been concluded. Within the last two years, several tuna investigations have been started and are now under way by several of our staff members. H. C. Godsil is investigating the causes of spoilage in refrigerated fishing vessels. Work on growth rate, movements and races has only started. D. H. Fry, Jr., has reported on weight loss by cleaning and cooking tunas in the canneries. Effects of present legislation are being investigated by H. C. Godsil.

"*Mackerel:* A study of the mackerel fishery was started four years ago. D. H. Fry, Jr., has conducted life history studies, especially growth determination and spawning. He has successfully hatched the eggs and reared the larvae in connection with oceanographic work on spawning. Richard S. Croker has sampled the commercial catch and written a report (Fish Bulletin 40, now in press) on the fishery in general.

"*Flatfishes:* The trawl fishery for flounders is being studied by G. H. Clark. This includes administrative questions in need of solution, life history studies and an analysis of the boat catches.

"Other species studied include:

"*Rock Bass:* Studies of this species were conducted by S. S. Whitehead and Frances N. Clark and reported by the latter.

"*Yellowtail:* G. H. Clark did some work on the sizes of this species appearing in the commercial catch, and S. S. Whitehead made an analysis of the boat catches.

"*Barracuda:* Life history studies by L. A. Walford were published, and a boat catch analysis was made by S. S. Whitehead.

"*Pismo Clams:* Population studies, originated by F. W. Weymouth, of the clams at Pismo Beach have been continued.

"*Oysters:* In cooperation with the U. S. Bureau of Fisheries, California is investigating and supervising oyster culture. Work for the State is being done by Paul Bonnot. This work is not under the direction of this Laboratory.

"*Shrimps:* Life history studies of the shrimps in the San Francisco Bay region are being made by Hugh R. Israil. This work is not under the direction of this Laboratory."

III. ILLINOIS—Dr. W. C. Allee, Zoology Department, University of Chicago:

"*Effect of Crowding on Growth of Fishes.* In nature it was found in 1931 (Cernajev) that size of ponds affects the rate of growth mainly through the regulation of the food factor. Other things being equal, the larger the pond, the more food; frequently, of course, other things are not equal. Only in small space per individual, according to 1931 results (Cernajev), does space act directly as a limiting factor on growth in fishes.

"With fishes, the possibility of increased growth-rate as a result of exposure to biologically conditioned water seems firmly established. There has been general testimony from aquarists that the presence of snails is beneficial in fish culture. In an attempt to test and analyze this phenomenon, Shaw (1932) grew *Platypoecilus maculatus* in filtered potable well water in which fresh water mussels had lived for the preceding 24 hours. The growth in length of such

fishes was compared with that of similar fishes in similar water differing only in that no animals had lived therein; feeding and other culture methods were identical in the two lots which were run simultaneously. At the end of thirty day growth periods, the mean percentage increase of those in conditioned water was 6.3, in unconditioned water, 2.7. Appropriate tests showed that the filtered conditioned water had no direct food value, i. e., fishes isolated therein without food showed a decrease in length. The presence of mussels has a beneficial effect on the rate of growth of fishes in water to which has been added a sub-lethal dose of $HgCl_2$ or NH_4Cl.

"Repeated experiences in this and other laboratories have shown that homotypic conditioning, if extensive, retards growth of fishes and other animals. Working in association with Dr. J. C. Welty and Mr. R. Oesting, I now have evidence that growth stimulation can result from such conditioning if carried on under appropriate conditions. The water used in our experiments is an artificial pond water made from distilled water and high grade analyzed chemicals.

"In the first five experiments which are all that have been tabulated as yet, the fishes in the conditioned water grew 2.2 times as rapidly during the test period of 30 days as did the accompanying controls. Analyses of the factors involved are being actively carried on. More complete data will be presented at the Christmas meetings of the American Society of Zoologists.

"Effects of Numbers on Amount of Food Consumed. The effect of crowding upon rate of food consumption has been reported by Welty (1904-1932) with *Notropis atherinoides,* and *Carassius auratus.* These fishes ate more *Daphnia* of a standard size if crowded than if isolated and showed reversals in numbers eaten if fishes previously isolated were placed together and those previously crowded were isolated. As the fishes became accustomed to the experiment, they tended to consume more *Daphnia.* Ordinarily an excess of those crustaceans would be introduced at the beginning of the feeding hour; those remaining after sixty minutes of feeding would be removed. When the fishes came to require such large numbers that the grouped fishes were swimming in a veritable swarm of *Daphnia* at the beginning of their feeding period, their rate of consumption fell off. It was restored to former proportions by adding fewer *Daphnia* at any one time but introducing them repeatedly during the feeding period. It was as though the fishes were over-stimulated by the presence of so many *Daphnia* and became "confused."

"Despite the greater amount of food known to have been eaten per individual by grouped goldfishes, the only ones tested for growth, they actually grew less than did the isolated controls. These results held true even when there was the same amount of water present per fish. It may be that the lessened growth is an expression of the often demonstrated growth-retarding effect of contaminated water. At least this simplest explanation must stand until there is experimental evidence to the contrary.

"Effects of numbers on respiration. Schuett (1933) has demonstrated with four species of fishes, *Lebistes reticulatus, Umbra limi, Carassius auratus* and *Fundulas heteroclitus* that when four fishes are present in a given volume of water, the amount of oxygen consumed per fish is lower than is the amount used by a fish isolated into the same volume of water. This group effect on respira-

tion is reversible and the rate of oxygen consumption of any individual fish can be altered by increasing or decreasing the size of the group within the limits tested. The same group effect occurs in goldfishes in flowing and in non-flowing water. When the volume per fish is the same for the grouped and isolated fishes, the difference in oxygen used in quiet water, the only condition tested, becomes insignificant.

"The factors lying back of this group effect upon respiration are unknown. The effect itself has been confirmed for goldfishes by Bowen (1932) and by Escobar (unpublished). Working with the closely schooling *Amieurus melas,* Bowen found the opposite effect; the grouped bullheads used more oxygen per individual than did the accompanying isolated controls. The difference in the respiratory behavior of goldfishes and bullheads is correlated with the different behavior of the two types of fishes when aggregated. With the goldfish Bowen and Schuett found no observed difference in the swimming behavior of the grouped and isolated fishes. Welty from longer contemplation of the behavior of these fishes reports that the grouped fishes are less likely to sudden starts and are more likely to engage in steady exploratory movements. The *Amieurus* on the other hand clearly act differently when grouped than when isolated. If aggregated each individual tends to push in towards the center of the group and the increased activity is reflected immediately in the increased oxygen consumption on the part of members of the group.

"*Effects of Numbers on Rate of Learning* (Work of Welty, 1932, 1934). *Umbra limi* can be trained to jump out of water for food when a red light is turned on. They jump less readily if more than one is present in the same aquarium. Opposite effects of numbers present on rate of learning are found when goldfishes are trained to run a very simple aquarium maze. In the numbers tested, viz: 16, 8, 4, 2 and 1, the rate of learning varies directly with the numbers present in the maze and is most rapid with the largest number tested. Untrained fishes learn to run the maze sooner if a trained fish is present than (a) if all are untrained, or (b) if a fish is placed in sigh as a lure in the reward chamber. Fishes that have watched others learn to run the maze will themselves learn more readily than will those which have not had this experience."

—Dr. Victor E. Shelford, Illinois Natural History Survey, Champaign:

"It is an open question whether or not organisms absorb dissolved organic matter."

IV. MICHIGAN—Dr. Carl L. Hubbs, Curator of Fishes, Museum of Zoology, Ann Arbor: Studies of species and races of fish, growth of sunfish and creel census work.

V. NEW BRUNSWICK—A. H. Leim, Acting Director, Atlantic Biological Station, St. Andrews:

"The following investigations in marine and freshwater biology have been carried on in 1932 and 1933. Studies in the life histories, food and distribution of the important food fishes, including the haddock, cod, herring, and hake in the bay of Fundy and near Halifax; life history of the lobster; growth studies of the scallop, clam and squid; reproduction and growth of oysters; sex reversal of oysters; effect of varying temperatures, salinites and of light on oysters,

clams, lobsters and other aquatic animals; effect of oxygen content of the water on the development of oyster larvae; plankton of the Halifax area; hydrography of the bay of Fundy and Halifax and its relation to marine animals; primitive bacteria of sea water; yellow coloration in clams; life history of the salmon of the St. John river system; observations on salmon in Apple river, N. S., food of salmonids; fall runs of salmon in the St. John, Magaguadavic and Digdeguash rivers; salinity relations of salmon; survey of Chamcook lakes and Loch Lomond, N. B., and Lake George, N. S.; disease in eel-grass; hydrography of the waters of the Halifax area; chemical investigations of sea water in the Halifax area (phosphates, oxygen, etc.); light in relation to water; effects of light on aquatic organisms; comparative surface water temperatures."

—Dr. R. H. M'Gonigle, Biological Station, St. Andrews:

"The work with which I am associated may be briefly summarized as investigations into fish mortality causes, and development of ways of prevention. In particular the work has meant during the period mentioned, study of each individual case of hatchery mortalities of unusual or unexpected severity. Much of this, especially the early mortality, seems to be associated with an 'egg weakness'—often hereditary, but also acquired. To improve hereditary egg-weakness feeding studies have been attempted—so far without marked success.

"We are also studying various methods of egg hatching, chiefly using recirculated water to better control the various factors (temperature, etc.). This work is still under way.

"We are also studying various ways of rearing fish more economically to larger sizes by using fertilized water. This work is just starting. Various means of fertilizing are being used and studied."

VI. NEW YORK—Dr. Emmeline Moore, Research Biologist, Conservation Department, Albany:

"Besides the fisheries investigations included in the Biological Survey, the Division of Fish and Game has initiated other long-range cooperative studies with Cornell University scientists, working in the fields of nutrition and hatchery practice."

VII. NEW HAMPSHIRE—Dr. H. P. K. Agersborg, Department of Fisheries and Game, Concord:

1. Physical, chemical and biological surveys of cooperative trout rearing pools. Forty pools studied, thirty-five in active operation. Similar work completed at the State Fish Hatcheries and rearing pools. Changes are checked at three-month intervals.
2. Hard water can stand more crowding with trout than soft water.
3. A relationship was noted between double-headed monsters and the hydrogen ion concentration of the water. Methods were developed to avoid this trouble.
4. Determined cause of white spot disease (intestinal *fungisitosis*) and how to prevent it.
5. Selective breeding and feeding of brook and rainbow trout.
6. "The State of New Hampshire has experienced less loss of young fish this year than ever before in its history, although the hatcheries have been over-

crowded five times their capacities. The State has, therefore, this year not only more but larger and healthier fingerlings than ever before. This is due to two things: (1) injection of scientific methods into trout culture; (2) new, and better trout food and better methods of feeding. The trout food used by the State of New Hampshire is absolutely fit for the best table in America. We use ten assorted species of fish less than 12 inches long; sheep liver and heart; salmon egg meal and whole salmon eggs; and *Mytilus edulis* and fresh crabs."

7. A better grade of trout obtained by taking eggs from native wild fish than from fish taken outside the State.

VIII. ONTARIO—DR. W. J. K. HARKNESS, Department of Biology, University of Toronto, and co-workers:

1. Life histories of fish parasites.
2. Spawning habits and embryology of the gar pike and dog fish.

IX. QUEBEC—G. R. LANE, Lucerne:

1. Parasites and food of speckled trout.
2. Parasites of lake trout.
3. Numerous bass tapeworms, *Proteocephalus ambloplities* (Leidy) were found in smallmouth and largemouth black bass during 1932, but in 1933 very few of these parasites were observed.
4. Experimental work on the kinds and quantities of fish food necessary for trout.

X. TENNESSEE—Papers abstracted by DR. E. B. POWERS, Department of Zoology, University of Tennessee, Knoxville:

"The physiology of the exchange of gases through the membranes of the respiratory organs of aquatic and terrestrial animals is the same. There is an essential difference in the morphology of the respiratory organs of lung and gill breathers, the lungs being more of a closed system and the gills more of an open system. In respiratory adjustments the lung breathers can control within limits the external environment while gill breathers must depend more upon the blood as a physiological-physico-chemical system for adjustment."

"Relation of carbon dioxide and oxygen contents of the blood to carbon dioxide and oxygen tensions of the environmental water. The volume per cent of oxygen of venous blood increases with an increase in the oxygen tension of the water and *vice versa*. The volume per cent of the carbon dioxide in the venous blood increases with an increase in the oxygen and with an increase in the carbon dioxide tension of the water and *vice versa*."

"Effect of oxygen and carbon dioxide tensions of the water upon the number of red corpuscles in the blood of the channel cat, *Ictalurus punctatus* (Rafinesque). The number of red corpuscles is increased with a decrease in the oxygen and by an increase in the carbon dioxide tension of the water and *vice versa*."

XI. U. S. BUREAU OF FISHERIES—DR. ELMER HIGGINS, Washington:

"Practical results of the bureau's investigations in the interest of improved fish cultural practices have been evidenced by a sustained output of large and vigorous fish from the bureau's many hatcheries in the face of reduced

appropriations. Studies conducted at the three experimental hatcheries have shown the feasibility of extensive utilization of cheaper ingredients in the diet of trout and the utility of fertilizers and forage fish in the economical production of bass and other warm water fish. Trout breeding experiments have likewise demonstrated the superiority of selected strains of brood fish over wild stock in increased egg production, in more rapid growth, and in resistance to disease. It has been shown that hatchery production can be increased four times by doubling the rate of growth and the number of progeny from a single pair through selection of the brood stock. Progress has been made in solving the problems of sanitation and prophylaxis against disease in hatcheries and in disseminating such information for the practical application in producing fish hatcheries.

"Cooperative investigations of the nutritional requirements of trout carried on jointly by the New York Conservation Department, Cornell University, and the Bureau of Fisheries at Cortland, N. Y., have progressed satisfactorily where synthetic diets have been employed in testing the vitamine requirements of trout and their ability to digest the various food materials."

XII. WISCONSIN—Dr. Chauncey Juday, University of Wisconsin, Madison:

"Growth studies of different species of fish in different types of lakes have been made. These growth studies include perch, rock bass, bluegills, ciscoes and suckers. It has been found that the same species of fish shows very different rates of growth in different bodies of water. Through the cooperation of the anglers of the State, a study of the rate of growth of game fish has been carried on and a report dealing with these results was issued in April, 1933.

"The alimentary tracts of some 5,400 specimens of fish have been examined for the purpose of determining the kind and quantity of food eaten by them. A report on this work is now ready for the press.

"The external and internal parasites of some 5,000 specimens of the various species of fish have been studied; the various species of parasites have been determined and the abundance of these parasites in the various specimens. The relation of these parasites to the intermediate hosts, such as Mollusca, birds and Copepodsa have been studied. A correlation between abundance of parasites and rate of growth has been found in perch. There is also a certain correlation between the character of the water of a lake and the abundance of the parasites.

"We are also using fertilizer on one of the small very soft water lakes in order to increase its production on plankton. A combination of lime and phosphate has increased the growth of phyto-plankton very materially in this lake."

The fruits of scientific research must be applicable to the practical operation of conservation problems because without some application it is questionable if conservation funds should be utilized for the work. Judging from the above reports and from titles of papers on this year's program, it seems as if the practical fish culturists and the scientists are beginning to talk the same language.

Discussion

THE PRESIDENT: Is there any discussion on this very complete report presented by Mr. Wickliff?

MR. RODD: The percentage of loss referred to by Dr. Clemens in sockeye salmon is based on the number of eggs contained in all the adult sockeye salmon that reached Cultus Lake. This is based on an average number of eggs per female of 4,500. The percentage, therefore, is based on the possible production of eggs.

REPORT OF THE DIVISION OF COMMERCIAL FISHING

JOHN VAN OOSTEN

In this report I wish to call the Society's attention to some of the recent developments of interest to the commercial fishing industry as well as to certain other information of importance to this industry.

FISHING GEAR

Measuring Mesh of Twine—One of the most troublesome questions in the enforcement of regulations governing the size of the mesh of twine in fishing concerns the method of measuring twine. In most of the methods now in vogue, the establishment of the legality of any mesh depends almost entirely upon the person who makes the measurement. This has of course been the source of much friction, not only between the fishermen and the Conservation officers but also between the fishermen and the manufacturers of netting and even between the officials of different states. In fact, the question of the method of measuring mesh has even been the underlying cause of the failure of one international agreement.

Due to the unsatisfactory method of measurement, Conservation officers have been known to lose their cases in the courts, resulting not only in a subsequent laxity in the enforcement of the laws on mesh but also in a haphazard, irregular, non-uniform enforcement of these laws. The question, no doubt, is present wherever laws regulating the size of mesh are enforced, but it is especially acute in the Great Lakes area. It has come up repeatedly at the fishermen's conferences on the Great Lakes and has always played a prominent rôle in the deliberations of the International and Interstate Conferences on the Great Lakes.

In December, 1929, I presented the problem to the Bureau of Fisheries with the request that the Bureau of Standards be asked to cooperate. This it did. After extensive experimentation the two Bureaus issued recently a joint mimeographed report in which specific recommendations are made for determining the size of mesh in gill nets. It was found that the principle of using a flexible gauge would be most satisfactory under all field conditions, provided the gauges were made as specified by the Bureau of Standards. Work on heavy twine of impounding nets has not been completed. It is hoped that as the result of this work the method of measuring twine will be made uniform throughout the country.

Preservation of Nets—It has been estimated that the investment in fish nets in the United States amounts to about $16,000,000, and that the annual cost of replacement of nets to the fishing industry is around $7,000,000. For several years the Bureau of Fisheries has been investigating the causes of deterioration of twine and at intervals has announced the results with respect to certain preservatives. Great advances have been made in the prevention of fouling and in the prolongation of the life of the nets. Anyone interested in the most recent recommendations for preserving twine should refer to Memorandum S-330 published by the Bureau at the beginning of this year.

Fishing Boats

Trap-net Boats on Great Lakes—With the introduction of deep trap-nets on the Great Lakes in 1928 came the need for improvements in the boats attending these nets. Hand winches were replaced by power winches to facilitate the lifting of these huge nets in deep water and the old trap-net boats with a speed of about eight miles per hour were replaced by newly designed boats with modern engines which develop a speed as high as twenty-four miles per hour. High speed boats were required because of the increase in the distance to the nets in deep water. Runs of twenty-five miles to the fishing grounds are not uncommon now for trap-net boats whereas formerly such runs were seldom attempted.

Radio Telephones—The installation of radio telephones on ocean trawlers is a noteworthy advance in the progress of fishing. Through this device captains are notified from shore where big runs of fish have been located, when to hurry to port to take advantage of increased prices or to remain at sea and escape a slump in prices. Further, captains are enabled to summon medical aid in emergencies by airplane and thus obviate the necessity of returning to port.

Fishery Products

New Products—Research is continually expanding our knowledge concerning the value of various species of fish in the production of liver oil, fish meal, and fish flour. The most recent research on liver oil involved the halibut, the haddock, the sablefish, and the burbot or lawyer of the Great Lakes. Quite an important market has already been developed for halibut oil. Other researches are under way to improve the quality of fish meals and to produce fish flour suitable for human consumption.

An interesting new product that has appeared on the market is the fish sausage recently developed by a Seattle concern. This sausage is made from salmon and cod, smoked, sliced, machine ground, and stuffed in cellophane casings. Each sausage weighs about a pound, has excellent keeping qualities, and may be kept in a refrigerator for weeks.

The process of filleting fish is being extended to new varieties, especially among the fresh-water species. Just recently the whitefish, that delicacy of the Great Lakes, has joined the ranks of the fillets.

New Methods—Recent laboratory experiments conducted by the Bureau of Fisheries point to a possible improvement in freezing fish by substituting a

coating of cottonseed oil for ice glaze and thus reduce the loss of weight from evaporation. In the experiment oil glazed fish lost 5.3% of its weight while the ice glazed fish lost 22.7%. Another experiment conducted by the Bureau of Fisheries that has commercial possibilities is the construction of a smokehouse, so equipped that it will enable the operator to control all the factors under which the fish are smoked and thus produce any type or standard product desired. The Biological Board of Canada also demonstrated recently that by employing an air conditioning machine fish may be dried for smoking in a much shorter time than is possible by wood drying fires, and in many cases the sheen on the fish was improved thereby.

A novel innovation in technique of recent date is the new method of opening oysters and clams for the removal of live meats. The specimen is put asleep by certain acids; its muscles relax; the animal gapes (or shall I say yawns?); and while thus in this unconscious and helpless condition it is robbed of its most precious belongings.

Under the subject of methods reference should be made to the recent standardization of market grades for fish by the states of Minnesota, Virginia, and Massachusetts. In each state the fish are examined and graded by state inspectors and the approved packages are marked with the official certificate or stamp.

Transportation

Transportation facilities have made great strides forward. Fish are now being moved to market not only by greatly improved refrigerated railroad cars but also by refrigerated vessels and auto trucks. Airplanes are now regularly engaged to haul nothing but fish, a certain firm in the East even contemplating the operation of its own planes. The operation of refrigerated planes is but a matter of time.

Advertising Campaigns and New Outlets

Attention is called to the recent widespread advertising campaigns to increase the consumption of fish and make the nation "fish conscious." Radio broadcasts, attachment of "Eat More Fish" labels on packages and mail, and "Eat Fish for Health" ads painted on railroad refrigerated cars are some of the new methods employed. It is said that more than twenty railroad cars have already been decorated with such ads. An experiment is being carried on in providing new outlets for fish. Chain stores handling fishery products only have been established in Los Angeles and have met with success, and an expansion to about 500 stores west of the Mississippi River is now contemplated.

Statistics

Methods—Repeated reference has been made at these meetings to fishery statistics. I am now pleased to report that the United States Bureau of Fisheries has begun recently the first detailed, biological analysis of the statistics of the Great Lakes fisheries. The very complete statistics collected by the State of Michigan are being used as a basis to develop

methods of study. A report covering the special methods which have been developed to apply to Great Lakes conditions will be presented to the Society at this meeting.

Yield—Statistics of the catch for 1932 have not yet been compiled for the United States but those for Canada, which no doubt will indicate the trend for the United States also, show a decrease in production on both coasts and on the inland lakes as compared with 1931. The total catch by commercial fishermen of the Dominion in 1932 was 816,383,000 pounds in round figures, as against 959,775,000 pounds in the year before, a decrease of 15%. In the sea fisheries of the Atlantic coast, the 1932 landings amounted to slightly more than 413,177,000 pounds, a decrease of about 21,000,000 pounds, or 5.1%. In British Columbia, the sea fisheries catch for the year was approximately 347,495,000 pounds, as compared with 464,996,000 pounds in the year before, a decrease of 25.3%. The total landings from the inland fisheries were 55,711,000 pounds in 1932, as against slightly less than 60,440,000 pounds in 1931, a decrease of 7.8%.

Depletion of Whitefish by Deep Trap-Nets

At the meeting last year Mr. Westerman presented a paper on the recently introduced deep trap-net of the Great Lakes and pointed out the danger of its unrestricted use in taking whitefish. A bill to control this net in Michigan was killed during the past session of the legislature by activities of lobbyists. What I wish to point out here is that Mr. Westerman's prediction came true, for according to the most recent information available all of the most important whitefish grounds in Michigan, except one, have been depleted and good lifts are reported only for those grounds where deep trap-nets have not been fished or where they have been fished less than two or three years. Every whitefish ground fished three years or more with deep trap-nets has been depleted.

Uniform Regulations

An important step forward was taken by the Province of Ontario and the States fronting Lake Erie in securing uniform regulations on this lake, when their representatives signed an agreement drawn up at Toronto on December 2, 1932. By this agreement the destructive bull net has been abolished, the size of mesh in whitefish gill nets increasd to 4¾ inches, and a uniform closed season established. In this connection reference should be made to the N.R.A. Under this act the fishermen of the Great Lakes and elsewhere now have a golden opportunity to secure the uniform regulations that they have desired for decades. To encourage such a move the Bureau of Fisheries has drawn up and published, a few days ago, a list of suggestions for uniform regulation of the Great Lakes fisheries.

Other recent developments in the fishing industry might be referred to but I believe I have given you the "high lights," and I hope you have not been bored too much by their recital.

Discussion

MR. FRED WESTERMAN (Michigan): I think Dr. Van Oosten is to be congratulated on the splendid report he has made for the Division of Commercial Fishing, dealing as it does with a matter which in certain states at least is a very important one. It is the most excellent report we have had from this division in many years, if it has ever before been approached.

THE PRESIDENT: I think we all agree with you on that point, Mr. Westerman.

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

GUY AMSLER

This report must, for a number of reasons, be brief. Last year the able vice-president whom I succeeded presented a most complete and commendable survey covering progress made during the preceding year by the various states and the national government in the protection of various species of game fish. My report will in a measure supplement that given by Mr. Denmead at the 1932 convention of the Society.

During 1933 legislatures in forty-three states have been in session and, while flattering results were not widespread or the progress hoped for made, there was considerable encouraging legislation enacted. The urgent appeal sent out last year by the United States Bureau of Fisheries, insisting that better protection be provided for the black bass, seems to have fallen on fertile soil, at least in many commonwealths, as a majority of new regulations were calculated to increase this universally admired species.

In this connection it might not be amiss to comment on the apparent soundness of the Bureau's concern over the black bass situation. Prophesying is unbecoming and ancient, but it surely is not improper to suggest as an evident fact that unless strenuous and effective action is forthcoming the black bass is a doomed species. The Bureau's appeal should command a hearty response. This noble member of our finny tribe should be protected and encouraged to the utmost in its uphill fight for perpetuation.

After an unsuccessful fight during the regular session of the General Assembly in Alabama last year, the sportsmen of that state came back with a "bang" and at an extra session enacted a measure prohibiting the sale of black bass caught in the state, provided a daily and possession limit of not exceeding ten, and fixed a size limit of eleven inches from tip of nose to fork of tail. The new law also prohibits exporting game fish from the state except by non-residents holding proper licenses, and provides additional protection for species other than black bass. A part time, non-resident fishing license—good for a period of seven days and costing $2—was also provided.

The cities of Baltimore, Cumberland, and Hagerstown, Maryland, have passed ordinances prohibiting the sale of black bass in those cities regardless of where the fish are taken, and five states passed state-wide measures of a similar character. They are Rhode Island, North Dakota, West Virginia, Kansas and Oregon. Missouri placed a size limit on black bass and other game fish. Arizona decreased its daily limit on black bass from fif-

teen to ten and on trout to twenty. My home state of Arkansas adopted a ten inch size limit on black bass, also provided size limits on other species and fixed daily creel and possession limits on bass and other game fish. West Virginia increased the size limit on black bass from eight to ten inches. Tennessee increased the size limit on bass taken from Reelfoot Lake from nine to eleven inches and thereby eliminated a considerable amount of commercialization of small fish.

Only two states apparently were successful in providing closed seasons on black bass during the spawning season. Arkansas enacted a new regulation in this connection, while Oregon extended its local law to a statewide law. It is unfortunate that more states were not able to provide protection at a time when it is so badly needed.

There was seemingly a more decided move during the past year toward the non-resident part-time or trip license than has been apparent heretofore. Ten states provided non-resident part-time angler's licenses. They are Alabama, Vermont, New Hampshire, West Virginia, Wyoming, Maryland, Iowa, North Carolina, Maine and Michigan. This makes a total of seventeen states with laws providing for a non-resident trip or part-time license. West Virginia is issuing to residents of Ohio a non-resident license to fish in the West Virginia waters of the Ohio River for the sum of $1. Mississippi increased its non-resident fee from $2.50 to $5.25, while Louisiana reduced the fee from $5 to $2 for non-residents, and from $1 to 50c for residents. North Dakota likewise reduced its resident fee from $1 to 50c, while Maine reduced its non-resident part-time license from $3.15 to $1.65, and Arizona repealed a law providing for a fifteen day trip license, the cost of which was $2.50. New Brunswick held out further invitation to the tourist angler by providing a trout and salmon seven-day license which costs $5. In so far as we have been able to determine, Arizona is the only state in which the part time license has not met with favor.

Legislation designed to better protect the black bass was considered but without favorable action in Maryland, Indiana, New Mexico and South Dakota. A number of states provided additional protection for game fish other than the black bass. Unfortunately, we do not have a complete list of these with the subject matter of the acts.

In last year's report, Mr. Denmead, as vice-president of the Division, criticized, and rightly so, the fact that the widely advertised city of Hot Springs, Arkansas—the Nation's Health Resort—dumped its raw sewage into beautiful Lake Hamilton, from which it was carried into Lake Catherine. As most of you know, these two lakes, Catherine with over one hundred miles of shore line and Hamilton with two hundred and forty miles of shore line, resulted from water power development activities of the Arkansas Power and Light Company. They represent one of the outstanding fishing places of the Southwest and the dumping of raw sewage into these splendid waters has been a source of great embarrassment and concern to the sportsmen of Arkansas, as well as the State Game and Fish Commission. It is highly pleasing and encouraging, however, to report to you at this time that arrangements have been perfected for the installation of a modern

waste disposal plant for the city of Hot Springs, and it is only a question of a very few months until this lamentable condition will have been remedied and another victory credited to the activities of this organization and the sportsmen of the Southwest.

Perhaps the most discouraging and outstanding back-set that we have experienced during the year is the discontinuation of federal activities in the protection of black bass and the administration of the federal black bass law. Doubtless many of you saw, not many days ago, a communication from Commissioner Bell saying that federal activities in the administration of the black bass law had been reduced to a minimum and that it had become necessary, as a retrenchment movement, to dispense with the services of one of our members who has rendered outstanding service in national wild life administrative affairs—Talbott Denmead.

It goes without saying that this is a distinct blow to national efforts in behalf of the black bass and I am strongly of the opinion that the work should be re-established on a broader basis than heretofore at the earliest possible date.*

I should add that Michigan reduced its non-resident annual angling license from $4 to $2, and provided that the wife of a licensee might obtain a license upon payment of fifty cents.

Last night I received a communication from Commissioner Bell which contains some additional facts pertaining to new legislation. Among other things he says:

"Before considering the question of state legislation I wish to bring to your attention the fact that the Bureau has recommended that there be included in the Coal Code to be adopted under the N.R.A. a clause providing for the sealing of abandoned mines; and in the Fish Code a provision prohibiting the sale of black bass."

I should like to suggest to the commissioner that he also include in that the sealing of abandoned oil and gas wells.

"The Public Works Administration has granted to the Bureau the sum of $300,000. The expenditure of much of this money will ultimately enure to the benefit of the game fish; at the same time the Civilian Conservation Corps may assign part of its forces concentrated in the many camps to work providing for the improvement of the streams, again constructively aiding in game fish protection."

Then he goes into a discussion of the changes that have been made in the various states; I believe I have already covered that. Then he says:

"California shortened the open season on black bass and other spiny-rayed fishes.

"Colorado made some changes in its open seasons in lakes and streams at certain altitudes.

"Connecticut reduced its daily limit on trout to fifteen.

"Idaho opened Bonner and Boundary counties to year around fishing and lengthened the closed season in Kootenai County to sixty days.

"New Mexico extended its trout season to November 15th (this was regulatory rather than legislative action).

"Ohio provided a special resident and non-resident trout license, including other game fish."

He says further:

"The law regulating the catching of fish in Lake Murray, South Carolina, was amended to provide for a daily limit of ten bass and/or trout with a size limit of 6 inches.

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*The Department of Commerce later made arrangements to continue the black bass administrative work under Mr. Denmead.

"Utah closed Fish, Navajo and Blind Lakes, on the Boulder Mountain, to game fishing October 1st rather than October 31st, and guides are not permitted to take fish from the waters on which they are guides.

"The County Game Commission system, under Initiative Measure No. 62, passed by the State of Washington last November, is superseded by the State Game Commission."

Discussion

THE PRESIDENT: Is there any discussion of Mr. Amsler's report?

THE SECRETARY: Before we left Washington we were assured that the black bass administrative work of the Bureau of Fisheries would be continued. There are certain details to be worked out, and I had hoped that that would be done in time so that Mr. Denmead, who has been in charge of that work, would be able to come to this meeting—we always like to see Mr. Denmead at the sessions of the American Fisheries Society.

In connection with the sealing of abandoned gas and oil wells, the Public Works Administration has allocated something like $628,000 to the Geological Survey, part of which is to be used to seal abandoned gas and oil wells, and the balance to seal abandoned mines, mostly open pits in Montana, Wyoming and through that part of the country. I think they had in mind not so much the benefit that would accrue to fish life as the desirability of closing these abandoned gas and oil wells and mine openings to prevent domestic livestock, and once in a great while some human being, from getting injured or temporarily lost in one of these places.

A movement is now under way in a number of states that are most seriously affected by mine drainage here on the Ohio watershed to have such work done there, and we hope it will be successful. We are urging that the Public Works Administration set aside half a million dollars and detail the job to the United States Bureau of Mines or some similar agency. It has been found, after considerable experimentation by the Bureau of Mines experimental laboratories at Pittsburgh, that by simply closing out the air and letting the water flow in the usual way mine water from abandoned mines will not be destructive or injurious. Oxidation is reduced to a minimum, and the flow from abandoned mines, when properly sealed, is not injurious to the fish life.

In my own state of Pennsylvania ninety per cent of the mine water which makes one important stream absolutely uninhabitable for fish is coming from abandoned coal mines. If this effort should be successful it would materially reduce the flow of deleterious matter into many of our fishing streams.

MR. C. C. REGAN (Kentucky): A week ago last Thursday the Department of Game and Fish in Frankfort, Kentucky, received a long distance telephone message from the president of one of our protective game fish associations at Ashland, Kentucky, stating that tons of dead fish were floating down the Ohio River. After investigation and telephone calls as far as Parkersburg, West Virginia, we discovered that these fish were afloat above Parkersburg. We immediately wired the Conservation Departments of Pennsylvania, West Virginia and Ohio, and in telephone communication with the department at Harrisburg we asked them to make investigations. We have since received a letter stating that they had sent one of their pollution men and a man from the Fish Department to make the investigation.

At that time they were not in a position to say what was the cause of the death of these fish, but they presumed it was attributable to acid conditions or other pollution arising from the opening of some of the industries around Pittsburgh that had been idle for two or three years. I happened to be in Ashland last Saturday, and I found that the reports were not exaggerated, that perhaps never before have so many dead fish floated down the Ohio River as were observed over a period of about three days, commencing on Wednesday evening and continuing until Sunday morning. The water was literally covered with all species of fish.

It seems to me this would be a fertile field for legislation; it is too bad that after all the efforts of state conservation departments in the propagation of fish for streams of that description, factories and industrial establishments should wantonly destroy fish in such large numbers. I simply want to leave with you the thought that the folks in Washington would possibly be in a position to remedy that condition by legislation that would apply as an interstate proposition. It would be pretty hard for Kentucky, Ohio, Pennsylvania or West Virginia to control a condition arising perhaps above their boundary lines and out of their jurisdiction; what is necessary is a national law, if it can be so arranged. It certainly seems like a travesty upon sound conservation to destroy fish in such great numbers.

The President: Mr. Amsler asks that those who know of any additions that should be made to his paper advise him so that he can make the proper revisions before publication.

Dr. George W. Field (Washington, D. C.): These two questions of the handling of the black bass and the killing of fish by pollutants and other deleterious substances have been very close to me for a good many years. As you perhaps know, my first efforts in this line were met by the politicians of a certain state who said: "This stuff you are putting out is neither agriculture nor science, and it must stop." I told them that my understanding was that I had been hired for experimentation, to see whether these things were science or agriculture, and that my decision was to be considered in the matter rather than the merely political aspects of it. The result was I resigned and have been working on these things ever since.

The black bass situation had its prototype about 1906 or 1907 in the case of the killing of yellow pike or pike-perch in Missisquoi Bay. Governor Fiske of Vermont came down to the state house in Boston and stated the situation, and we went to see Governor Guild. Governor Guild pointed out that there was a necessity for interstate action with regard to the matter. I told him I was going downstairs to draw up a law to prohibit the sale of these fish in Massachusetts—most of them were caught in Swanton, Vermont, and shipped down to Boston and sold in the market there. We notified the fishermen in Swanton that any fish they shipped in contravention of this law would be seized. We tried to stop it at Swanton, but if we did not stop it there, we would stop it at Boston. That worked for a time, but finally the fishermen began to ship to Providence and to New York; ultimately, however, it stopped. The point there was that the fish should not be taken at the time they could be caught most abundantly;

the fish of Lake Champlain were accumulating in Missisquoi Bay for spawning and the fishermen were catching them at that time in great quantities.

With regard to the aspect of pollution, I have just received information from England to the effect that their commercial fisheries are falling away as ours are, and they are pointing out that efforts should be made to counteract that tendency by artificial propagation and the rearing of fish in ponds and reservoirs on a commercial scale. We have to meet that same situation in this country.

REPORT OF THE DIVISION OF ANGLING

S. B. Locke

In a scientific organization such as the American Fisheries Society there are not as many features which naturally relate to the Division of Angling as to other Divisions. It is very easy to lap over into other subjects since practically all of them influence angling, but I am attempting to avoid this.

Perhaps the greatest influence affecting angling is the continuous increase in the number of people who enjoy it. This not only builds up the importance of angling but carries with it increased activity in all fishery branches in which the Society is interested.

Unemployment and more leisure time create a greater demand for all forms of outdoor recreation, but angling more so than others due to its universal appeal to all ages and classes.

A minimum investment of only a few pennies is necessary to share in certain forms of the sport and the thrill for the boy catching his first "sunny" is as great as that of the mature disciple of Walton in capturing a salmon or muskie.

The policy of acquiring public rights along streams which has been initiated in some states, particularly Connecticut and Massachusetts, is of great importance to anglers. These rights, either in the form of purchase or by leases which may result in later purchases, will insure public waters for fishermen. Such a policy coupled with the purchase of forest lands, the reservation of public lands in the West, and rights on navigable streams and lakes, place the angler in a much better position than the hunter in the opportunity to exercise his sport.

In the Great Plains States, particularly North and South Dakota, Nebraska and Iowa, a program of water restoration and conservation has been initiated which will greatly increase the waters available for fish production. A general interest in maintaining the water table level, preventing erosion and providing waterfowl areas has contributed support to this movement which will result in much improved conditions for fishing.

Another factor having an important influence on angling is the Civilian Conservation Corps activities. Reforestation work indirectly will be most beneficial in improving conditions for fish life. There is also the direct work of the Corps in stream and lake improvement, particularly in Michigan and Iowa, and also within the National Forests. This has not only the direct benefit in improved angling but serves as a demonstration to encourage similar work by other public agencies and sportsmen's groups.

Another development of much value to anglers is the great stimulus of sewage treatment plant construction by provisions, first for loans from the Reconstruction Finance Corporation where such loans could be retired by rental charges, and second in the National Recovery Act allowing direct payment from federal funds up to thirty per cent of the cost with loans for the balance. Many municipalities are taking advantage of this opportunity to advance sewage treatment. A conspicuous example is in the Willamette River, Oregon, where pollution was rapidly exterminating fish life. The larger cities in the Willamette Valley—Portland, Salem and Silverton—voted for sewage treatment plants at recent elections, as did Medford and Grants Pass in the Rogue River Valley, Roseburg in the Umpqua Valley, and Baker and Burns in Eastern Oregon.

The Reconstruction Advisory Board for Oregon has recommended to the federal body thirty-eight sewage treatment plants in the Willamette Valley and nine in other parts of Oregon.

In all these projects there has not only been the immediate results of benefit to anglers but also the advantage resulting from establishing public understanding of these activities as a permanent public benefit.

A distinct recognition of the importance of angling has been given in the so-called "Copeland Report" prepared by the Forest Service, U. S. Department of Agriculture, in response to Senate Resolution 175 (72nd Congress). This report, which presents "A National Plan for American Forestry," contains a chapter on Fishery Management in Forest Waters of the United States by Henry O'Malley, former Commissioner of Fisheries.

The paper treats the influence of forests on fish life, economic and social values of fish in forest waters, fishery management, and methods of carrying into effect a program of fishery management in the forest areas. Included in the information on economic and social values of fish life was the interesting statement that 4,850,000 state licenses were sold carrying the privilege of fishing, for which eight million dollars were paid. Twenty-five million dollars were spent for tackle. State and Federal fish cultural stations employed 1,500 men and spent $4,500,000 in operating costs. The production from their operations was one billion game fish. The production of fish for angling is very definitely indicated as a responsibility in connection with the management of public forest lands and game fish as a valuable product of all forest lands.

APPOINTMENT OF COMMITTEES

Auditing—A. B. Cook, Jr., Chairman William J. K. Harkness, Albert M. Powell.

Resolutions—Guy Amsler, Chairman, E. L. Wickliff, George C. Embody, Abraham Wiebe, B. O. Webster.

Time and Place—Eben W. Cobb, Chairman, John L. Farley, Carl L. Hubbs, James Brown, C. F. Culler, J. A. Rodd, W. J. Tucker.

Nominations—E. Lee LeCompte, Chairman, T. H. Langlois, John Van Oosten, D. N. Grim, Charles O. Hayford.

Program—Fred A. Westerman and Abraham Wiebe.

REPORT OF COMMITTEES

AUDITING COMMITTEE

MR. COOK (Michigan): Your Auditing Committee has checked the books and vouchers of the treasurer for the fiscal year ending June 30, 1933, and finds the report as submitted to be correct.

Our president informs the committee that he accompanied the treasurer to the vault of the Riggs National Bank in Washington, D. C., last week and assisted him in checking the Permanent Fund securities of the Society, and that the report of the treasurer concerning said securities is correct.

Your committee recommends that the total appropriation for clerical and stenographic services for the year of 1933 and 1934, exclusive of expenses in connection with the preparation, proof reading and indexing of the Transactions, be the same amount as last year, namely $350.

Your committee wishes to commend our treasurer upon the splendid condition of the books.

THE PRESIDENT: You have heard the report of the committee; what is your pleasure?

MR. LECOMPTE: I move the adoption of the report.

MR. T. SURBER: I second the motion.

The motion was agreed to.

COMMITTEE ON RESOLUTIONS

MR. AMSLER: Mr. President, as Chairman of the Committee on Resolutions I have the honor to report that we have eleven resolutions to present.

The resolutions are as follows:

Proposed House of Representatives Committee on Wild Life Resources

WHEREAS, The Special United States Senate Committee on Wild Life Resources has materially advanced the general cause of conservation through extended studies and congressional proposals; and

WHEREAS, A resolution, sponsored by the Honorable A. Willis Robertson of Virginia, is now pending in the House of Representatives to set up a similar committee in the House of Representatives;

THEREFORE BE IT RESOLVED, That the American Fisheries Society endorse this proposal and urge the House of Representatives to add this proposed committee in order that the nation's wild life resources may be better conserved;

BE IT FURTHER RESOLVED, That the Secretary of the Society immediately bring this resolution to the attention of the proper authorities.

Sealing of Abandoned Coal Mines

WHEREAS, The Public Works administrator of our Federal Government has available large sums for allocation to various uses which will create employment and aid in the conservation of our natural resources; and

WHEREAS, Experiments made by the United States Bureau of Mines conclusively prove that by sealing abandoned mines to prevent air from entering such openings oxidation will be stopped and the water therefrom will not be injurious to our streams;

THEREFORE BE IT RESOLVED, That the American Fisheries Society urge Honorable Harold L. Ickes, Public Works Administrator, to allocate a sum of at least $500,000 to some Federal agency like the United States Bureau of Mines for the sealing of abandoned coal mines in the Ohio River watershed;

BE IT FURTHER RESOLVED, That the Secretary of the Society immediately bring this resolution to the attention of the Public Works Administrator, and that a copy be sent to President Franklin D. Roosevelt.

Floating Sardine Reduction Plants

WHEREAS, Floating Sardine Reduction Plants operating beyond the state's jurisdiction off the California coast are reducing sardines without restriction;

WHEREAS, Adequate protection of the important sardine fishery depends upon the control of waters beyond the three-mile limit;

BE IT RESOLVED, That the United States Government be urged to enact such legislation or enter into such treaties as may be necessary properly to protect the sardine fishery of the West Coast of the United States; and

BE IT FURTHER RESOLVED, That copies of this resolution be sent to the proper Federal officials and congressional committee members.

Great Lakes Fisheries

WHEREAS, The commercial fishermen of the Great Lakes have for decades recognized the need of uniform regulations for the administration of the fisheries of each of the several lakes; and

WHEREAS, The Agricultural Adjustment Administration now provides the opportunity to effect the enactment of such uniform regulations; therefore

BE IT RESOLVED, That the American Fisheries Society urges the fishing industry to include in its formulation of a code for submission to the Federal Government proper and adequate uniform regulations for the protection and control of the fisheries in each of the Great Lakes.

BE IT RESOLVED FURTHER, That, in the event of the failure of the fishing industry to embody in its code such uniform regulations, the Federal Government be urged to exercise its powers to the end that these regulations be included in the code which is to govern the conduct of the industry.

BE IT RESOLVED FURTHER, That copies of these resolutions be submitted to the following associations and executives:

U. S. Fisheries Association, Midwest Fish Producers' and Distributors' Association, Fishermen's Cooperative Association, Minnesota North Shore Fishermen's Association, Wisconsin Commercial Fishermen, Commercial Fishermen's Association of Michigan, Michigan Commercial Fishermen's Protective Association, Lake Erie Fish Producers' Association, Lake Erie Fishermen's Association, the Honorable Henry A. Wallace, Secretary of Agriculture; the Honorable Frank T. Bell, Commissioner of the United States Bureau of Fisheries; Mr. R. H. Fiedler, Deputy Administrator for Fisheries, Agricultural Adjustment Administration.

Black Bass

WHEREAS, The progress in black bass legislation has been quite encouraging during the past year, both in the matter of stopping the sale of black bass and providing closed seasons during the spawning period, with suitable length and creel limits; and

WHEREAS, Thirty-two states now absolutely prohibit the sale of black bass, no matter where taken;

THEREFORE BE IT RESOLVED, That the American Fisheries Society strongly recommend to the remaining sixteen states that they so amend their legislation at the first opportunity as to prohibit the sale of black bass at all times, regardless of where taken;

BE IT FURTHER RESOLVED, That eight states which do not provide adequate closed seasons to protect game fish during the spawning period be urged to enact proper legislation without delay.

BE IT FURTHER RESOLVED, That the Secretary of the Society be instructed to send a copy of the resolution to each of the sixteen states.

Pollution

WHEREAS, The waste products of many industrial operations when discharged into the open streams and waters of the country are very destructive to public values represented in aquatic life, or are dangerous to public health;

WHEREAS, An adequate disposal or treatment of such wastes to prevent damage to our public waters is clearly in the interests of the public welfare;

WHEREAS, Some industrial establishments, in recognition of public values concerned, are incurring expenses incident to an adequate disposal or treatment of such wastes, which places them at a financial disadvantage in comparison to competitive establishments not subject to such expenses;

THEREFORE BE IT RESOLVED, That the American Fisheries Society at its sixty-third Annual Meeting at Columbus, Ohio, on September 20, 1933, strongly urges the administrators of the National Recovery Act to include in industrial codes, provisions setting a standard for all industries to adequately dispose or treat injurious industrial wastes and not discharge such in public streams to the detriment of public welfare.

Tennessee River Watershed Lands

WHEREAS, Authority has been granted to the Tennessee Valley Authority under Section 23 of the Norris Act to provide for the proper development of marginal lands in the Tennessee River watershed in relation to flood control, reforestation, and the development of natural resources;

AND WHEREAS, Competent opinion holds that the region offers excellent opportunity for the planning and execution of a long time program of controlled fishery development and aquiculture involving the use of power reservoirs for fish production, the widespread popular adoption of modern methods of fish farming as an adjunct to agriculture, and the promotion of sport fishing by scientific management, culture, stocking and improvement;

THEREFORE BE IT RESOLVED, That the American Fisheries Society recommends and urges the adoption by the Tennessee Valley Authority of a comprehensive program of fishery development and that steps be taken at the earliest practicable time to survey the region and assess the possibilities for such development, utilizing competent existing governmental and private agencies in devising and executing the technical and practical branches of the program;

BE IT RESOLVED FURTHER, That a copy of this resolution be sent to the Tennessee Valley Authority, to the United States Commissioner of Fisheries, and to the Governor of each state extending into the Tennessee River Valley.

Tennessee Valley Aquiculture and Fishing

WHEREAS, It has come to the attention of the American Fisheries Society and the hydrobiologists that a wildlife and recreational proposal has been submitted to the Tennessee Valley Authority by the Southern Regional Council of the American Game Association, and that their proposal has been endorsed by numerous interested organizations;

THEREFORE BE IT RESOLVED, That this Association and the hydrobiologists add their endorsement to that proposal, and forward to the Tennessee Valley Authority this resolution and memorandum concerning the joint recommendations of the American Fisheries Society and the hydrobiologists for the scientific development of the fish resources of the Tennessee Valley area.

MEMORANDUM

Addressed to the Tennessee Valley Authority by the American Fisheries Society
Concerning: AQUICULTURE AND FISHING IN THE TENNESSEE VALLEY

1. Any forward-looking plan for the development of a region should take into account the cultural resources of its waters and their utilization. The aquatic resources of this region are very great and largely undeveloped. There has been little or no aquiculture—only exploitation.

2. Land-utilization plans should include other and possibly better uses for some of the wet lands than the drainage of them. Pond culture in the flood plains and improvements for food and shelter of fishes in the hill streams may be more valuable.

3. Fishing and forestry go well together. They involve practices that are not conflicting but complemental. Fish raising brings early returns. Many successive crops of fishes may be had while a single tree crop is maturing.

4. The culture of fresh-water fishes adds variety to food supply and diversifies inland industries.

5. Fishing waters add beauty to any landscape. They increase the charm of the countryside. Their conservation will keep the waters clean.

6. Fishing, man's primeval occupation, is today our most general sport, available to both sexes, to all ages, and at all seasons.

7. Improved methods in fish culture have made much progress in our own day and are practical and profitable, although there is much need of further experimentation. It is now possible to begin aquiculture development in new places with confidence of success.

8. There is, in our judgment, no service the TENNESSEE VALLEY AUTHORITY could render our country at large greater than that of setting an example of scientific inland fish culture. This should proceed from a very moderate beginning with experimental testing out of methods, step by step, and with wide distribution of knowledge of results among the people, so that those favorably situated might be aided to undertake the improvement of streams and the construction of ponds and the raising of fishes for themselves.

9. For the guidance and control of the experimental part of such an undertaking there should be established one or more stations equipped for real work and manned by trained workers. Such are now unusually available since economy measures have dropped many technically trained and competent persons from fisheries payrolls, and hard times have prevented others newly prepared at the universities from finding an opportunity to use their training. Experiment station work of this sort would accomplish the double purpose of promoting aquiculture and relieving unemployment.

10. It is the research work of agricultural experiment stations that has made modern agriculture. Aquiculture may be promoted by like methods. The beginnings that have been made by federal, state and station investigators are to be commended. These point the way. The favorable attitude of the present national administration toward all forward-looking enterprises encourages the suggestion that experiment station work in the field of aquiculture be established as an integral part of the Tennessee Valley development, with land and water, equipment and maintenance sufficient to warrant the expectation of results of permanent value, not only to the Valley of the Tennessee but to the nation at large.

Resolution of Thanks

RESOLVED, That we express our grateful appreciation of the attractive program and the cordial hospitality which have characterized the sixty-third Annual Meeting of the American Fisheries Society and that we extend our sincere thanks especially to His Excellency Governor George W. White of Ohio, to His Honor, Mayor Henry W. Worley of Columbus, to Commissioner William H. Reinhart and his able associates of the Ohio Division of Conservation and to the officers of this Society for their efforts in making this a most successful, profitable and enjoyable convention.

We also express to the Columbus Chamber of Commerce and to the Press our sincere appreciation of the many favors granted by them which have been so helpful in guiding our activities in this beautiful city of Columbus.

We further express to the management of the Deshler-Wallick Hotel our deep appreciation of the many courtesies extended which have contributed greatly to the comfort and pleasure of our members and to the success of our meetings.

MR. LECOMPTE: I move that the resolutions be adopted.

MR. FARLEY: I second the motion.

(Mr. LeCompte's motion was carried unanimously.)

Game-Fish Policy

MR. FARLEY: Since the Committee has withdrawn the suggested resolution concerning an American Game-Fish Policy, I move you that the president appoint a committee to cooperate with the American Game Conference and other bodies in a position to give assistance in forming an American game-fish policy, and to report back to the meeting at the next annual session.

MR. ADAMS: I second that.

THE PRESIDENT: Is it your wish to designate the number?

MR. FARLEY: No.

(Motion carried.)

COMMITTEE ON TIME AND PLACE

MR. ADAMS: The joint Committees on Time and Place for the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners recommend that we accept the invitation of the Province of Quebec officially communicated to this Society, and that we leave it with the officers of the Province of Quebec to indicate at a sub-

sequent time whether they desire us to meet in the city of Quebec or the city of Montreal, both of which are in the Province of Quebec; and that the time of the meeting be the week starting the second Monday in September, 1934.

(On motion of Mr. Amsler, seconded by Dr. Wiebe, the report was adopted.)

COMMITTEE ON NOMINATIONS

MR. LECOMPTE: Mr. President, we have a list of officers to present which we have tried to work out geographically so that no part of the country has been missed. We recommend the following for your consideration:

Officers

President—Fred A. Westerman, Lansing, Mich.
Vice-President—E. L. Wickliff, Columbus, Ohio
Secretary-Treasurer—Seth Gordon, Washington, D. C.
Librarian—Eben W. Cobb, Hartford, Conn.

Vice-Presidents of Divisions

Fish Culture—B. O. Webster, Madison, Wis.
Aquatic Biology and Physics—Elmer Higgins, Washington, D. C.
Commercial Fishing—W. A. Clemens, Nanaimo, B. C., Canada
Protection and Legislation—Guy Amsler, Little Rock, Ark.
Angling—W. J. Tucker, Austin, Texas

Executive Committee

Fred J. Foster, *Chairman*—Salt Lake City, Utah
I. T. Quinn—Montgomery, Ala.
John L. Farley—San Francisco, Calif.
Eugene W. Surber—Leetown, W. Va.
James Brown—Montpelier, Vt.
L. A. Richard—Quebec, Canada
Sumner M. Cowden—Albany, N. Y.

Committee on Foreign Relations

J. A. Rodd, *Chairman*—Ottawa, Canada
W. F. Thompson—Seattle, Wash.
Fred C. Walcott—Norfolk, Conn.
W. C. Adams—Albany, N. Y.
Wm. D. Stewart—St. Paul, Minn.

Committee on Relations with Federal, Provincial and State Governments

Frank T. Bell, *Chairman*—Washington, D. C.
Harry B. Hawes—Washington, D. C.
John Van Oosten—Ann Arbor, Mich.
W. J. K. Harkness—Toronto, Canada
A. B. Cook, Jr.—Ionia, Mich.
O. M. Deibler—Harrisburg, Pa.
C. C. Regan—Covington, Ky.

The President: You have heard the report of the committee: what is your pleasure?

Mr. Surber: I move that the recommendations of the committee be adopted.

Mr. Locke: I second the motion.

(The report was unanimously adopted.)

The Retiring President: I will ask Mr. Surber and Dr. Greeley to escort the newly elected president to the platform. (Applause.)

Mr. Westerman was escorted to the Chair.

The Retiring President: Members of the American Fisheries Society, I take pleasure in introducing to you your new president, Mr. Fred A. Westerman of Michigan. I congratulate you, Mr. Westerman, upon the great honor which has been bestowed upon you, and I congratulate the Society upon the excellent judgment it has shown in selecting a president.

The President-Elect: Dr. Davis, I want to thank you for your kind words, and to congratulate you upon the success of this meeting, which I know is very largely due to your untiring efforts in its behalf.

Members of the American Fisheries Society, I thank you from the bottom of my heart for the distinct honor you have conferred upon me in electing me as president of the Society. I think this has been the finest meeting that I have been privileged to attend, and I trust that our meeting in the province of Quebec next year may be equally successful, as I believe it can be, with your help. I hope that you will all be there, as well as many of those who were unable to be with us at this meeting. Again I thank you most sincerely. (Applause.)

On motion of Mr. LeCompte, seconded by Dr. Wiebe, the Sixty-third Annual Meeting of the American Fisheries Society was adjourned.

In Memoriam

Hugo Crasser, Wyoming

Ernest Danglade, Indiana

John Y. Detweiler, Florida

Mrs. D. B. Fearing, Rhode Island

G. E. Jennings, New York

Phil Kopplin, Missouri

Charles E. Lewis, Minnesota

W. E. Meehan, Pennsylvania

J. A. Pinkerton, Minnesota

Andrew Gray Weeks, Massachusetts.

PART II
PAPERS AND DISCUSSIONS

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SOME EXPERIENCES AND SUGGESTIONS ON FORAGE FISH CULTURE

CARL L. HUBBS

Institute for Fisheries Research, University of Michigan

I think it is hardly necessary to explain to this group the meaning of forage fish; they are, of course, fish that are eaten by larger and more desirable species. The meaning of forage fish has been made known by the work of the United States Bureau of Fisheries, especially through the experiments conducted at the Fairport station; and through the publications of the Bureau and, in some degree, the publications of other institutions and state hatcheries.

The golden shiner is especially suitable for pond fish culture by reason of its breeding habits and its capacity to produce large quantities of small fry throughout the summer in ponds. We have had some experience in Michigan with this species. In experiments carried out for the Department of Conservation at Grand Rapids, Henry Schuil has found it possible in small experimental ponds to produce a very large concentration of golden shiner fry each year. He has recently reported considerable success in increasing that production through the fertilizing of the ponds. We need a continuation of these experiments so that we can determine in just what manner the largest production of these forage fish can be obtained.

In part of the experiments at Fairport, adult golden shiners were kept with the bass in the ponds and allowed to breed so that as both species spawned, shiner fry were produced upon which the bass fed. This method, according to the word I have had from the superintendents of hatcheries, has proved entirely unsatisfactory at other points. For instance, at the Dwight Lydell hatchery in Michigan the superintendent has informed me that the ponds in which golden shiner adults were kept produced practically no bass, and he is confident that the shiners eat the bass fry after they rise from the beds. Mr. Gill, of the Manchester, Iowa, station of the Bureau of Fisheries, has told me the same story. Apparently at both these places ponds in which there were adult golden shiners produced practically no bass fingerlings. In Texas the experience was the same. Mr. Burr sent me some golden shiners from one of the Texas hatcheries and asked me if I would please identify these minnows for him. He had thought they were golden shiners, but when these minnows were put into a bass pond the bass disappeared, and when he opened the minnows he found the bass there. He had understood that the shiners would not eat the bass fry, therefore what could these fish be? They were golden shiners, just the same. As a result of this and some other observations I think there is grave danger in keeping adult golden shiners in ponds in which the bass are bedding.

At Fairport that condition was not obtained, which I think is explainable. The Fairport water, pumped out of the Mississippi River, is extremely rich in microscopic life, and the golden shiners there have not eaten the bass fry. That, I think, can be explained by fish nature. Fish nature is very much like human nature: fish are lazy and will not make any more effort than is necessary to attain their ends. If there are plenty of water fleas to be eaten, they are not going to chase an active little bass fry. Furthermore, from the fact that the water was silty there is some question as to the ability of the shiners to see the bass fry clearly enough to chase and catch them. In clear ponds, especially those in which microscopic food life is not exceedingly abundant, I think the evidence is that the golden shiner will eat the bass fry and are dangerous. Moreover, there is competition in such ponds where there is a limited amount of microscopic life on which the earliest stages of bass feed, because the golden shiner feeds extremely heavily upon the water fleas and thus competes with the young bass for feed. As soon, however, as the bass reach a larger size and go about their way seeking larger mouthfuls, as is their custom, they give up this diet of very minute life and eat larger things, at the same time, of course, growing larger. The bass does not have to grow very large in order to be safe from the adult golden shiner, which has a small mouth; so it is perfectly safe, I think, to keep the adult shiners in with the bass after they have reached the No. 1 fingerling stage.

The blunt-nose minnow is another species with which we have had some experience, and it is a very interesting one. This minnow is abundant and widespread throughout almost all of eastern North America, entering almost all sorts of habitats, even living in the warmer trout streams and in lakes and ponds of all sorts. The spawning habits of this creature are a considerable aid to its culture. It has a habit of nesting under any flat object, if necessary scooping out an excavation under such an object so that the eggs are laid in one layer of the under surface of it; and it makes little difference what that flat object is. Along one lake I examined something like twenty such flat objects, and all but two had eggs of this species, or of another species with similar habits, underneath. These flat objects might be slabs of wood, flat stones, mussel shells, or even tin cans. The possibilities of production of this minnow were proved by Mr. Schuil in an experiment, in which we cooperated by obtaining adults to stock a quarter acre pond. In the fall 25,000 young of this minnow were obtained—that is production at the rate of 100,000 of these minnows per acre. There were no bass in that pond. Some difficulty was experienced in getting proper slabs for the fish to spawn on. There was probably an insufficient number of slabs, and I think the production could be increased even beyond 100,000 per acre. An interesting device was used in feeding these minnows—a submerged feeding trough

to which the minnows would go as pigs would to their feeding trough.

At the United States hatchery at Northville, as Mr. Carman, who is here, could tell you better than I, experiments have been run with this species and with the blackhead species, which has similar breeding habits. Apparently very good results in bass production were obtained through the use of this minnow in the ponds. Both species, the blunt-nosed and the blackhead minnow, were used, and a high percentage of the slabs of various sorts which were put into these ponds were utilized by the fish for spawning. On one of the slabs which Mr. Carman lifted out for us we estimated that there were somewhere around 20,000 eggs. Mr. Carman said he would count them; perhaps he can tell you what the count turned out to be. But there was a tremendous quantity of these eggs, apparently some of both species—because there seems to be a slight difference in the size of the egg of these two species, the blackhead having a smaller egg and more commonly laying the eggs not strictly in one layer but more or less in two layers.

There are other species which have similar spawning habits. There are the three kinds of darters, so called, which deposit their eggs similarly on the under side of flat objects. One of these, the Johnny darter, is a fish which will live in ponds and in lakes, utilizing such objects for spawning in quiet water. The fish we call the muddler in Michigan has the same habit. This species, also known to some of you as miller's thumb, is accused of being an enemy of trout through egg eating, but I believe the report which Dr. Greeley gave last year at Baltimore shows that any eggs that would be picked up by such fish are waste eggs anyway. There is a possibility of increasing the forage fish production in trout waters, in ponds and even in trout streams, by inserting flat objects on which they may spawn.

There are certain advantages offered by these two species, the blunt-nosed minnow or the blackhead or fathead minnow, in pond fish culture, especially in smallmouth bass ponds. These fish are not predacious on the fry; their mouths are entirely too small to eat them. They are bottom feeders; they eat very little plankton and are therefore less dangerous as competitors than the golden shiner would be. There is one possible disadvantage, and that is the fact that they are egg eaters, clustering about the nests of some fish and eating the eggs in considerable quantities if the adult fish is for some reason driven off the nest. That is a point which needs further study.

There is need for close scientific study of these forage fish, which I can illustrate by speaking of this blunt-nosed minnow, on which we are working. There is the problem of the growth of these fish; if that growth can be increased by providing the proper food for the fish, they will spawn earlier. In Michigan the larger ones spawn early in their second summer, that is, when one year of

age. I understand in Illinois there is evidence that they spawn even in the year of their birth. If they do that, a tremendous increase in production can be expected. There are probably animals which feed upon the eggs of these minnows. We have noticed at Northville a very large number of empty egg shells without a corresponding number of fish swimming about, suggesting that some enemy is seeking these slabs and feeding upon the eggs of the forage fish. We saw on these slabs such animals as flat worms, leeches and snails. During the past week I have had reason to suspect these flat worms as I watched them feeding upon daphnia in an aquarium. That is something that perhaps we have not suspected, and something that is of considerable importance, probably, in relation to the culture of water fleas. These little flat worms are terrific destroyers of daphnia; they will eat them in large numbers. Apparently the flat worm secretes some mucous in which the daphnia will become entangled in large clusters. You can see the flat worm move definitely toward these sticky masses, from which the daphnia cannot get away. Other animals probably are involved. It is important to determine what sort of animals can eat the eggs of these minnows; it is perfectly obvious that that is necessary if we want to produce minnow fry.

The greatest forage fish in numbers in the Great Lakes region is the lake shiner. This fish occurs in tremendous abundance in the waters of the Great Lakes. During the inshore movements of these fish in the spring and fall they come in in such enormous schools that they actually darken the water. The value of these fish as forage fish for the commercial species of the Great Lakes is considerable. They not only directly feed the fish which are commercially valuable, but they satisfy the fish predators. We determined this in the investigation of tern on Saginaw Bay, where the tern was found to feed almost entirely on this fish. Inasmuch as this fish is so excessively abundant and can be obtained in untold thousands in a few seine hauls, it has been considered as a possible forage fish for introduction into inland lakes to feed the game fish, and also for introduction at the hatcheries to feed the fish which are being reared there. These fish, as I say, are extremely easy to obtain; they are easy to transport; they will live over the winter in the lakes and in the fish ponds, and serve excellently as food for bass, especially when the bass begin feeding in the spring.

At the Dwight Lydell hatchery it was found, however, that these larger adult shiners will eat the bass fry quite easily. We have found another point of interest in this connection, and that is that the lake shiner apparently does not reproduce, at least we have as yet had no evidence that it reproduces, either in the ponds in the hatchery or even in the inland lakes where they have been introduced. Adults will live there and continue to live, but we have no indication that they spawn under such circumstances.

The gizzard shad is of tremendous importance as a forage fish. It is the most efficient biologically of all the forage fishes. The gizzard shad eats the minute plant life in the water and itself is eaten by the game fish. It is the only species of fish we have which in anything like that degree acts as a single link in the chain between these elementary microscopic plants and the adult fish. In Buckeye Lake here in Ohio there is a tremendous production of game fish, most of which feed upon the gizzard shad; in fact, the gizzard shad is held by the investigators in Ohio to be responsible for the wonderful production of that lake. The same thing holds true for Lake Herrington in Kentucky, which by general reputation is one of the finest bass fishing lakes in the country. It is true also in other lakes and reservoirs in Ohio and Illinois. I think any program involving forage fish in fishing waters, especially in the reservoirs of the states in this general region, should include consideration of the gizzard shad.

Just a few remarks regarding the importance of this forage fish culture problem. It is quite evident that fingerling production can be increased through forage fish; the work of the United States Bureau of Fisheries at Fairport has, I think, shown that. It is certainly true that ordinarily fish need fish in order that they may grow large. Natural fishing waters can have their fish production increased by an increase in the forage fish in those waters. There is another aspect also, that of providing bait minnows through the rearing of forage fish. This seems to be commercially practicable; when it can be shown that they can be reared at the rate of 100,000 per acre. It seems desirable that fish be reared for sale as minnows since there has been a large depletion of minnows in our natural waters, making it difficult to obtain minnows to fish with. Furthermore, if bait minnows can be reared and sold sufficiently to supply the demand, seines can be outlawed completely and to that extent illegal fishing can be prevented. There are disadvantages involved in this, particularly with regard to goldfish. It is not at all certain that goldfish will not spread and take over our inland lakes. They certainly have spread and become something of a nuisance in Lake Erie, and they may well do so in the inland lakes, so it is a matter that will need watching.

I can only close with one thought, and it is this: I do not believe you would have listened to such a presentation as this ten years ago, at least with any considerable degree of attention. A discussion at that time of what kind of food these tiny minnows in the lakes used and what are their methods of reproduction would have passed as some little playtoy of a college professor. But judging from the amount of correspondence we have had on this subject and from the interest which has been shown in its obvious importance, I think we can say that it is now a live problem, and that what was regarded ten years ago as a scientific playtoy has

become a matter of practical application. This change in attitude is, I think, a fortunate one which promises much for the future. It is a development that has been made possible by the mutual understanding arrived at between the practical man and the scientific investigator. The practical man has been a little more generous in his attitude toward the work of the scientific man, and the scientific man in fisheries work has come to be willing to tackle problems which are practical in their application.

Discussion

Mr. Langlois (Ohio): Dr. Hubbs may be interested in knowing that last spring we transferred a batch of adult gizzard shad to one of our largemouth bass rearing ponds, and that they spawned there successfully. The largemouth bass have been feeding on them very successfully this season.

Dr. Bangham (Ohio): Another thing in favor of the gizzard shad is that they have very few parasites. The lake shiner has a good many that go directly to the bass and some of the other larger lake fish.

Mr. Hogan (Arkansas): With regard to forage fish placed in rearing ponds is it possible that we may get too much fertilizer in for the small minnows? As I understand it, daphnia can stand more than the bass. Is it possible that the small minnow fry may be killed by fertilizer?

Dr. Hubbs: There might well be a possibility of that, because minnow fry are quite sensitive.

Mr. Hogan: Probably more sensitive than fingerling bass.

Dr. Hubbs: That is the experience we have had in studies we have made on the effects of certain toxic material on fish life—that bass have withstood the application of chemicals much better than the minnows we have used. I think that is entirely possible. It is just another illustration of the need for investigation of this type of problem.

The President: That has been our experience also, Dr. Hubbs. It is undoubtedly true that the average minnow will not stand anything like as much as the bass. As a matter of fact I do not know of any fresh water fish, with the possible exception of the catfish, that will stand as many unfavorable conditions as the black bass.

Dr. Harkness (Ontario, Canada): What is the northern limit of the gizzard shad?

Dr. Hubbs: Georgian Bay, the Great Lakes region. It occurs in Georgian Bay and Saginaw Bay essentially as a sporadic invader; apparently it does not have a permanent residence that far north. It is permanent in Lake Erie.

Dr. Harkness: In waters north of Lake St. Clair you might not be successful in getting production in bass waters.

Dr. Hubbs: There was a big population of gizzard shad in Lake St. Clair and all up through the southern part of Lake Huron and Saginaw Bay this last year. In some years there is a big population there, and in other years there are none. Lake Erie, I believe, is the furthest north where there is a heavy population of gizzard shad.

MR. RODD (Ontario, Canada): What forage minnow would you recommend, Dr. Hubbs, for a lake into which speckled trout have been introduced and which had been barren before the introduction of that species?

DR. HUBBS: A number of species which occur in Canada might be considered. The redbellied dace perhaps would be best if you have a considerable quantity of vegetation. It is quite possible that this miller's thumb, or *Cottus*, as we call it scientifically, could be used as forage fish. They make fine bait, and certainly are tremendously enjoyed by the trout. I rather think they might be cultivated for that.

MR. RODD: They would not prey on the trout eggs?

DR. HUBBS: They will eat trout eggs, but Dr. Greeley's work indicates that in streams the trout eggs are hidden so far under gravel that any eggs which would be eaten by such little fish would be waste eggs which had floated off anyway and certainly would not reach maturity. I believe this problem of predators on trout eggs is not as serious as formerly it was thought to be. A sucker coming along and picking up a few eggs below a trout nest does not mean that that sucker is having anything to do with the trout production, because the sucker is not going down six or eight or ten inches into the gravel to get at good eggs; he is simply taking waste eggs.

MR. RODD: These lakes I have reference to are fed not by inflowing streams but from higher surrounding hills, probably underground springs or something of that nature. The trout have done extremely well in those waters which were previously barren; the growth in two years is really remarkable.

DR. HUBBS: Perhaps you had better leave the biological balance alone, if it is good.

MR. RODD: These lakes are owned principally by clubs, who are becoming concerned over the fact that the production of insects is not sufficient to keep up their trout population, and are urging the introduction of a forage minnow. The red bellied dace has been introduced into some of them, with, so far, no detrimental effects.

DR. HUBBS: The northern form of red bellied dace has such an extremely minute mouth that he certainly could not be suspected of eating a trout.

MR. RODD: Probably there would be less danger from the red bellied dace than from any other fish you have mentioned?

DR. HUBBS: I would think so.

DR. EMBODY (New York): I want to endorse what Dr. Hubbs has said about the propagation of minnows for sale to fishermen. Certainly it is true that the minnow gatherers are going to exterminate our minnows if something is not done. It is going to be necessary, I think, for us to propagate our own bait fish, and the question is, what fish shall we use for propagation purposes. And then the question of size comes into it, because the fish which will produce most economically will be the one that is produced in one summer's growth. I have thought about the question a great deal and have tried out a number of species for that purpose, but we never could raise the golden shiner or the blunt-nosed minnow to a large enough size. This year we tried out the chub sucker and also the

European pearl roach. The chub suckers, at least those we have, will not far outgrow the blunt-nosed minnow, but the European roach, which looks very much like the golden shiner, although it is a silver rather than a golden fish, seems to outgrow anything we have tried out. We have them now of this year's hatch which are three inches long. So far as the numbers produced is concerned, it should exceed anything we have ever tried. Moreover, they spawn all summer long. We have fish in that pond now that are anywhere from one inch to more than three inches long. As a fish to be introduced into a pond with young bass, however, it would not do because it is fully as predatory as the golden shiner; but if the bass could be raised in some adjacent pond and allowed to forage into the pond where the minnows were, it might work all right. That was the principle we had in mind in developing the series of ponds this year; we raised the forage fish in one pond and kept the bass in another, and when the bass reached a certain size we turned them into the minnow pond. The bass had been raised up to that point on daphnia alone, but Mr. Langlois' proposition knocked that all out, so that we are raising bass by feeding them artificial food.

DR. WIEBE: There are several things I would like to say in connection with Dr. Hubbs' paper. In the first place it is undoubtedly a fact that the introduction of the golden shiner at Fairport has not only increased but has multiplied the production of bass fingerlings. I think one reason why it has been so successful there is the extreme turbidity of the water. I made this experiment last year: I put a certain number of bass fry and a certain number of adult shiners in a tank of clear water, and a similar number of shiners and bass fry in a tank of turbid river water. In the course of a few hours the fry in the clear water had all disappeared, and the only cause to which to attribute their disappearance was the shiners. In the turbid water only a relatively small number disappeared during that same period, but apparently it is just a matter of time, for eventually they cleared up the fry.

With reference to the sensitivity of shiners to oxygen, I made a few observations last winter with regard to the oxygen consumption of golden shiners as well as the blunt-nosed minnow, and I find it is considerably higher than that of largemouth black bass. I think it would be far easier to get conditions that would be unfit for the shiner than for the bass. At Fairport we got quite a number of golden shiners that were three inches long, some of them four inches, during the short summer they had to grow.

One difficulty in connection with the blunt-nose and the blackhead that Dr. Hubbs did not point out is with regard to the size of the adults. You have to keep a separate stock outside the bass ponds, because even your larger bass fingerlings will clean up your minnow brood stock, and you have to have a separate pond to keep a supply of brood stock on hand. At Burlington, Iowa, we introduced some gizzard shad, I think at the suggestion of the United States Bureau of Fisheries, and now they are spending money to take them out, filling up big flat boats with them and

dumping them on the land to get them out of the pond. It does not seem to work out there at all.

MR. JOHN L. FARLEY (California): In California, where trouble was encountered with shiners and it was necessary to get forage fish in a hurry, resource was had to the bluegill sunfish, which proved a very successful forage fish during the summer season. The president can probably tell you more about that than I can, because he is more familiar with it.

THE PRESIDENT: We have had a good deal of success with the bluegill sunfish as a forage fish for crappie, but for some reason the results have not been so encouraging when used with bass. I do not know just why it is; we have not really followed it up to any great extent. But we find that when using bluegills with crappie the production of crappie was much greater than without the sunfish, and they also reached a considerably larger size during the summer. In addition to that we got a pretty good production of bluegills, and they also reached a larger size than they do ordinarily, because the crappie kept the numbers of the bluegills down. The greatest trouble with the bluegill is that they reproduce in such large numbers that unless you are very careful your ponds will be overstocked. You will get perhaps two or three hundred thousand bluegills to the acre and they will all be so small that they are not of much account.

MR. RODD: Has anyone found that the introduction of minnows into a speckled trout lake has had a tendency to make the trout bottom feeders as against surface feeders?

DR. GREELEY (Michigan): I do not think I can answer that directly. I have seen a good many large lakes where there was an abundance both of speckled trout and of minnows. Quite often the speckled trout fishing with the fly is rather difficult in these bodies of water except around the inlets and spring holes, but they do at times get good fly fishing. Cranberry Lake in the Adirondacks produces very many large trout, and the lake is full of minnows; the brook trout range the whole lake and grow to a great size. But only at times is there good fly fishing, and that is always in the inlets and spring holes.

DR. HUBBS: I would like to raise a question as to the advisability of rearing in our waters fish like the pearl roach, European fish of unknown capacities. We should keep in our minds the fact that there is danger in introducing exotic species, especially if there is some native species which reasonably can be expected to take their place.

With regard to the chub sucker, in an experiment we tried in Michigan we got a very fine size—beautiful bait minnow size in the first year, but a rather small production. Out of, if I recall aright, sixty adults in a quarter acre pond, we obtained only three or four hundred fingerling fish, but they were quite sizeable for fishing purposes.

MR. ALLIN (Kentucky): In Lake Herrington in Kentucky, a lake which was first formed some ten years ago, there were very few native fish—that is, game fish such as largemouth and smallmouth and Kentucky bass, and also the crappie. The Kentucky Game and Fish Commission placed in there something like 25,000 bass, and that is all the game fish that had

been placed in that body of water until last year. Last year we placed in there something like 250,000 of different species of game fish. We found in making a survey there this summer that over 18,000 pounds of bass had been taken out of Lake Herrington in one day. The gizzard shad is the main food of the game fish there. If it were not for the gizzard shad we feel that our supply of bass would fall down very materially.

THE PRESIDENT: What is the approximate area of Lake Herrington?

MR. ALLIN: It has a shore line of 333 miles. The length from the dam to the backwater is 36 miles. The water at the dam is 286 feet deep. The shore line is very rocky—limestone cliffs on one side, and in some instances on the other shore you have a gradual slope, all the old timber being left there. We tried another scheme on Lake Herrington—the use of floating bass nests—which worked very successfully. The idea was to try to prevent the loss of fish on account of the fluctuations in the water level. We placed thirteen of these nests in this body of water, and a nice brood was produced on each one of them. To show you how much sense fish really have—I have always said that a bass has more sense than ninety per cent of the people who fish for him—ten minutes after this first nest was placed in the water there was a pair of bass on it spawning. With the water temperature at 58 these bass eggs hatched in five and one-half days. Ordinarily it takes seven days in that body of water.

THE PRESIDENT: The idea of using floating bass nests is novel, but it strikes me it has great possibilities in reservoirs where there are great fluctuations during the breeding season.

MR. ALLIN: We are working on another project in the form of a floating fish hatchery, which looks as if it is going to help us a good deal in the propagation of bass.

DR. FIELD: With regard to the pearl minnow, I had an opportunity to make some observations on the part it plays in fish culture in Europe, particularly on the Rhone watershed. The pearl minnow is used there as food for the carnivorous fish. It is one of the main crops of fish, and incidentally it serves as food for introduced fish. The pearl roach is one of the five standard fishes in the fish cultural operations in the Rhone watershed. In the younger stages it serves as food for the pickerel and trout the same as our minnows here, but their method is altogether different from ours. They do not go in for unit fish; they make a combination which will work together. They develop the young herbivorous fish which will serve as food for the carnivorous fish, and they like the pearl minnow—poisson blanc—because in their market it is much like our smelt in ours. Notwithstanding this, the pearl minnow in its younger stages serves as food for the more valuable fish. When they are fully grown they are no longer useful as food for fish, but are used as food for man.

MR. LINCOLN (Michigan): Dr. Hubbs has excused the muddler from eating the trout eggs for the reason that he could not find the eggs. I wonder if he has any experience in determining what percentage of trout fry and small fingerlings the muddler will destroy.

Dr. Hubbs: I cannot answer that. I have a faint suspicion there would be some loss.

Mr. Lincoln: We planted trout fingerlings up to an inch and a half to two inches long in the deep pools where the muddler is found, and we noticed they took the fingerlings up to and including two inches, especially the larger muddlers.

REARING LAKE TROUT TO MATURITY

THADDEUS SURBER
Superintendent Fish Propagation, Minnesota Department of Conservation

It will no doubt interest many members of the American Fisheries Society to learn that we have met with a considerable measure of success in our efforts to rear lake trout to maturity at our Lanesboro Hatchery in Minnesota.

The attempt to do so was made necessary by our inability to procure a sufficient stock of eggs by the usual means to stock our inland lakes. Weather conditions in extreme northern Minnesota have always prevented us from operating at the proper season when the lake trout are spawning, consequently we have been forced to purchase or obtain through exchange with either Michigan or Wisconsin other eggs for lake trout eggs with which to stock these lakes.

On March 24, 1928, we transferred from our French River Hatchery on Lake Superior to the Lanesboro Hatchery 21,200 eggs which hatched on April 16. These were all about the usual size, running 200 per ounce. The fry began feeding after a very short time and made satisfactory growth and we shipped out of this lot on September 13, 19,800 fingerlings of an average size of four inches, retaining for brood stock 2,000 selected specimens. At the end of the first year they had reached a length of ten inches; the second year fourteen inches; the third year sixteen to eighteen inches; the fourth year eighteen to twenty-two inches and the fifth year, 1933, are now ranging between eighteen and twenty-six inches in length. The females apparently average somewhat larger than the males.

These fish have been reared entirely in cement ponds after they were removed from the hatchery at the close of the first year. The ponds are constantly supplied with pure spring water at a temperature ranging from 46° F. to 48° F. After reaching an age of two years they were examined for possible egg production, but we saw no indication of their producing any eggs until last fall. On October 26, 1933, or at the age of approximately four years six months, ten of the females produced 9,620 eggs, which ran 385 per ounce, or but slightly over one-half the size of the eggs produced by the parent stock. These produced approximately 8,000 fry hatched on December 26, or about sixty days after they were taken and fertilized. At this time they averaged about what the original stock did in 1928—four inches in length—and I do not find that we have any cripples or malformed fish among them. They take food greedily and have every indication of perfect health. There is no evidence of any disease among the adults, though they

are still retained in cement ponds. Some of the trout last winter were removed to a large dirt pond and held until this pond warmed up during the extreme heat of midsummer, when we found it necessary after losing a few to return them to the original quarters in the cement pond. While residing in the dirt pond they were forced to depend upon frogs and other natural food therein which apparently they did not like, because when we removed them in June they were in poor physical condition but still were perfectly healthy. About the only losses that have occurred in these fish at any time is due to the fact that some of them jumped out of the cement ponds, the sides of which extended above the surrounding ground, and inasmuch as this occurred at night they naturally died. These are the only losses that have occurred aside from those which could not withstand the high temperature during the extreme heat of June.

I might add that while we procure several million eggs from the commercial fishing in Lake Superior, our agreement with the commercial fishermen is for the return of all of the fish produced from these eggs to the waters of Lake Superior, hence our inability to restock inland lakes which had or were becoming depleted. From the condition of the fish at the present time we anticipate a good egg production because the fish show every indication of spawning in large numbers and at an early date.

It is rather surprising to note the change brought about in the appearance of this trout as compared to the type of fish from which the original stock was produced. While they have preserved the customary outline so far as length, depth and breadth is concerned, the colors and markings are both radically different and we can only assume that this is due to their having been reared in cement ponds in limestone water. The general olive colored background of the parent stock is replaced by a bright greenish olive darkening to steel blue on the back, with the dark spots intensified and the gray spots bleached out almost to whiteness. This produces an exceedingly handsome fish.

Discussion

Mr. Follett (Michigan): What did you feed these fish on?

Mr. T. Surber: We fed them mostly on beef hearts.

Mr. Follett: You do not think the growth was as rapid as it would have been in the state of nature, do you?

Mr. T. Surber: Yes, I think so. I think it is more rapid, because there was a longer growing season. There is a uniform temperature in those ponds winter and summer, and our inland lakes freeze up not later than the middle of October and remain frozen over until early in May or sometimes the middle of May. During that period of low temperature I doubt very much if the lake trout grow to any extent.

Mr. Follett: I have taken trout weighing 30 pounds in Lake Superior, and I doubt if you can raise them to that size in small ponds in captivity. I think the stock in these fish is all right for putting out again in the wild lakes; the fry would return to their normal condition.

Mr. T. Surber: The larger of these fish are twenty-six inches, as I state in this paper, at an age of four and a half years; that much is positively known. The average trout taken in our inland lakes does not exceed that length, regardless of what the age may be. Occasionally specimens are picked up weighing eighteen to twenty pounds, but in our inland lakes they never attain the size they do in Lake Superor. I imagine it is due altogether to the food, perhaps coupled to a certain extent with the low temperatures that prevail.

Mr. Follett: There is a lake in Vermont where the average size of lake trout is a pound and a half—that is Willoughby Lake, but I think it is largely due to the limited space and the limited variety of food.

Mr. T. Surber: I am positive it is the limited quantity of food in our inland lakes that prevents their reaching the extreme size they do in Lake Superior. One of our university men made a survey of one of these lakes this summer, and his report would indicate that it is pretty nearly a desert so far as natural food conditions are concerned. I am referring to one of the deeper lake trout lakes.

Mr. Follett: Of course as the supply of trout has diminished in Lake Superior, they have correspondingly reduced in size. I remember before the museum in Ottawa was burned they had the finest mounted specimens of lake trout I have ever seen—fish that would weigh forty to fifty pounds; it is a pity that these specimens were destroyed—we will never see anything like them again.

Mr. T. Surber: I might add that in addition to what I have said in this paper about our inability to procure eggs, it was an interesting experiment to me, because I have never read or heard anywhere of anyone experimenting with lake trout, probably due to the abundance of lake trout in the Great Lakes. But we were absolutely up against the problem there of restocking our inland lakes, and we had to do something. This is the result of it; I do not know what the ultimate result is going to be, but we have received a little encouragement from the experiments we have so far made. It certainly indicates that lake trout do not mature, at least in ponds, as soon as stream trout do, at any rate at corresponding ages; because there was no indication of spawning last fall, at an age of three and a half years.

Mr. Webster (Wisconsin): What was the temperature of the water in these ponds in which you were holding the fish, and what was the depth of the pond?

Mr. T. Surber: The temperature of the water is 46 to 48 degrees F. The depth of the ponds varies from about six inches at the head to two feet at the foot. The ponds are an average of six feet wide and forty feet long. But we have a large volume of pure spring water running through there continuously, not less than fifty gallons per minute to each pond, and sometimes that is increased to one hundred gallons.

MR. WEBSTER (Wisconsin): In Wisconsin we have never raised any fish to adult size, but we have had considerable experience in raising quantities of fish to fingerling size. We have at the Wild Rose hatchery at the present time about 20,000 fingerling lake trout that are about three to four inches long. As Mr. Surber says, it is almost impossible to kill them; they will live without any trouble at all—if we could raise other kinds of trout as we raise lake trout, there would be no difficulty. One of the fishermen in Wisconsin has carried out a tagging program that shows some very interesting growths; there is every indication that they grow twice as fast in their natural habitat as they do in inland waters, as Mr. Surber has indicated.

MR. T. SURBER: The hardihood of lake trout begins with the egg. During the winter of 1915-16, when I was at the Duluth hatchery—I was with the Bureau of Fisheries at that time—we held the last eggs we procured from southern Lake Superior on their shipping trays in the basement of the hatchery. We had no room to put them in our usual troughs. These eggs eyed just as well on the hatching trays where they were retained from early in December until the middle of February, as the eggs in running water. This shows the extreme hardiness of the lake trout. A few years ago I met a man on one of our inland lakes who was towing a large lake trout alongside of a canoe. He had carried it over a portage from the lake in which he had taken it the day before. It was a cool day and raining a little. He had to carry it over four more portages before he got it to where his car was parked. He took it home and put it in a bath tub of water, and it swam around as lively as could be. He had carried it over about six portages on this trip. Incidentally he carried this fish over the portages on a string run through the gills and thrown over the packsack. These lake trout will stand almost anything.

MR. WEBSTER: In Minnesota do you plant lake trout in other lakes than native lake trout lakes?

MR. T. SURBER: No.

MR. FOLLETT: The first time I visited Caledonia hatchery they had a lot of wild lake trout that had been taken from Lake Erie. They were kept there for show fish; the spawn did not develop. The same thing has been experienced with ouananiche and the male salmon—the wild stock kept in captivity would not reproduce.

MR. RUSS (New York): Two years ago this fall the eggs of this lake trout that were kept at Caledonia certainly did develop. Dr. Embody and I crossed some of them with brown trout.

MR. FOLLETT: That is different—I was referring to thirty or forty years ago.

DR. GREELEY (Michigan): In many of the inland lakes there is a considerable variation in the size of the lake trout. I have been reading a few lake trout scales this summer, and I find in some lakes you will get a lake trout seven years old that will be thirty inches long, while in other lakes at seven years they are nineteen and twenty inches. So that in comparing the rapidity of the growth of hatchery trout with wild fish, you can pick out from among your wild fish almost anything you want to—you have plenty

of leeway, because they grow very fast in some places and in others they do not.

Mr. T. Surber: I am confident that is so. I recall two small lakes in northern Minnesota right on the Canadian boundary that have never produced any lake trout in excess of about two pounds in size. I am positive that larger trout do not exist there, because commercial fishermen have gone into those two lakes with their nets and tried to catch larger trout and did not find them. I do not know what the ages are, but the mere fact that you found no larger ones in there would indicate that they grow to a certain size and then their growth is arrested and seems to go no further.

The President: What about the fertility of the eggs you took last fall?

Mr. T. Surber: The fertility of the eggs taken last fall was very good. These trout produced somewhat less than a thousand eggs each. We took eggs from ten females, 9,620 eggs, and they hatched 8,000. That, I think, indicates the average fertility of lake trout under normal conditions is high. That brings up a subject in which many of you people on the Great Lakes may be interested. About ten years ago we developed a plan of cooperation with our Lake Superior fishermen for the production of lake trout eggs. We were unable to get more than a million or a million and a half eggs, and a very low per cent of hatch from those eggs in that entire north shore country. So I hit upon a plan of interesting the fishermen themselves in properly fertilizing these eggs; we promised to pay them a small sum for the good eggs produced, and to deliver to the fisherman for planting on his fishing grounds the resulting fry. A lot of them, I found, had the idea that they could fertilize lake trout with whitefish. One fisherman at the mouth of the Pigeon had an idea that he could fertilize them the next day. I sent a superintendent to go out with these fishermen—there were something over two hundred of them—and he went out and gave them all the instructions he could on the taking and fertilizing of the eggs. Each lot of eggs is kept separate and is identified with the fisherman's name so that he can come in and ask to see his eggs, and during the last few years they have taken intense interest in them; in fact, there is a sort of rivalry among them to see which can produce the best quality of eggs. The result is we are getting, barring accidents caused by weather conditions, a ninety per cent hatch from the majority of these lake trout eggs.

THE GENERAL EFFECTS OF POLLUTION ON OHIO FISH LIFE

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It is plainly evident that any State desiring to maintain a maximum number of game and food fishes in its waters, or wishing to restock with these fishes, must take into consideration the factor of the so-called pollutions that may be present in their waters and are harmful to fish life. It would be, for instance, poor conservation to build a large series of fish hatcheries and produce thousands of fish yearly, only to plant them in polluted waters unsuited to their further existence.

Realizing the value of data on Ohio polluted waters and their sources of pollution, the Ohio Division of Conservation, cooperating with the Ohio Department of Health, has for several years past investigated the causes, effects and extent of pollution and consequently we now have a large amount of data upon this subject. Incidently, this has been most helpful to us in developing a stocking policy for Ohio.

To date, the major factors revealed by this investigation are as follows: (1) Possible methods of eliminating some of this pollution; (2) The sources and extent of the various pollutants now affecting Ohio waters, and (3) The general effects of pollution on Ohio fish life. The latter is the subject of this paper.

Preliminary to a discussion of the general effects of pollution on Ohio fish life it seems necessary to define pollution, to list the types of pollution which affect the welfare of fishes, and to mention briefly the nature of the effects upon the fishes.

Pollution, as used in this paper, is the addition to natural waters of any substance that is detrimental at any time to the fish inhabiting those waters. Pollutants may be classified according to their sources, according to their natures, or according to their various effects upon fish, and the last mentioned is the classification used in this paper.

Some pollutants affect the fish directly, such as through acids which incapacitate their delicate gills and may seriously injure other external parts. Pollutants of this kind are poured into the streams by steel mills, creosote plants, etc., chiefly located in the northeastern part of the state, though it happens also in isolated cases elsewhere in Ohio.

Other pollutants clog or cover the gills of fishes and so prevent respiration that death results; chief of these are the paper mill wastes, gravel pit washings and soil washings from corn fields. The last mentioned is of quite uncommon occurrence and is apt to occur only during extremely heavy rains when unusual amounts

of soil washings from newly cultivated fields drain directly into the streams.

However, the major effects of pollution are indirect, and the fish are harmed by changes of the stream bottom or of the water. Certain species of fishes, such as the bottom inhabiting or nesting species, are affected by the deposition of silts of the above, and other kinds on the bottom, as these deposits are unfavorable to the production of fish food and are detrimental or prohibitive to nest building operations.

Most pollutants which affect the water adversely do so by removing the free oxygen in solution upon which fish respiration is dependent, and although this is done in several ways the effect of this upon the fish is suffocation, and, in general, since the various fish species are quite consistent in their specific oxygen requirements, the elimination of fish species from a stream is accomplished usually in the same sequence when the method of injury is suffocation, regardless of what method the pollutant may use to remove the oxygen. For this reason only one example, the domestic sewage in the Scioto River from the city of Columbus, will be later used, and although it happens to illustrate the effects of removal of oxygen by domestic sewage, it may be considered illustrative of the other types as well.

The pollutants which affect the water adversely by removing its dissolved oxygen may do so in any of the following ways:

(1) The substance added to the water may lead to such a multiplication of aerobic bacteria that the bacteria use all of the oxygen the water contains. This type of pollution is probably the one most commonly encountered in Ohio, and it is estimated that at least 400 miles of Ohio streams, among which are some of the largest streams in the state, are affected by this type of pollution during some portion of each year. Sources of this type of pollution are municipalities, creameries, canneries, beet sugar factories and strawboard and paper mills. Pollution by domestic sewage is the most prevalent, as most communities void their wastes into streams, treated, partially treated and untreated. Creameries and canneries are widespread throughout the state, but in most cases the effluents have been treated and cause very little trouble, though there are some which periodically do considerable damage. Most of the beet sugar factories are located in the northwestern part of the state and they are in operation only in late fall and winter. During this period they cause high mortality of stream fish because of the great volume of their effluents, although the loss would be greater if the plants were operated during seasons of warmer weather. Strawboard factories are situated for the most part in central and midwestern Ohio, and while the majority of them treat their wastes, there are times when the treatment systems break down or become inadequate and the untreated wastes

are allowed to enter the streams with disastrous results to the fish life. The paper mills, though scattered widely about the state, are largely confined to central Ohio and to the towns along the Great Miami River in southwestern Ohio. Coupled with the bacteriological effects of these wastes there are also chemical effects.

Pollution of the bacteriological type is most malignant a short distance below the source, after the bacteria have developed and removed the dissolved oxygen from the water. From the point of greatest malignancy downstream a return to normal conditions is begun, the distance to the place where normal amounts of oxygen are again in solution depending upon the amount of pollution, temperature and the type of stream. At the place where the dissolved oxygen content is again normal there is likely to be an unusual abundance of phytoplankton and zooplankton and other fish foods, which results in a concentration of suckers and forage fishes, primarily minnows. Present also, and preying upon the forage fishes, are basses and other game fishes (so called) in unusually large numbers, and from this point downstream, therefore, it is evident that the domestic sewage may be considered beneficial rather than detrimental.

In warm weather when the stream flow is greatly reduced, there is apt to be an accumulation of organic debris below the point of entry, and when heavy rains come this accumulation may be washed downstream en masse. The progress of this material is marked by an oxygenless condition which results in the killing of those fish species which have a high oxygen requirement. If the oxygen content is only partially depleted the Gizzard Shad and Carp-suckers and Suckers of the genera *Moxostoma* and *Placopharnyx* will be killed. With the further reduction of dissolved oxygen the Basses and Sunfishes, Madtom Catfishes of the genus *Schilbeodes,* Channel Catfish, most of the species of minnows and darters and the Fine-scaled Sucker will be destroyed, and when the free oxygen is all gone the most resistant forms, such as the Bullheads of the genus *Ameiurus* and Carp, are killed and the stream is left barren.

The Scioto River below Columbus is an example of streams affected by domestic sewage pollutions, and the effects upon the fish life as mentioned hereafter may be considered illustrative of the typical effects of bacteriological pollutions of all kinds. In midsummer during periods of extreme heat and drought, only the Bullheads and Carp may be found in numbers for a distance of from five to ten miles below Columbus. From this point to near Circleville, which is located some thirty miles south of Columbus, the fish population consists of bullheads, carp and a few of the more resistant species of mid-water minnows, and it is not until well below the Circleville pollution zone that the complete stream population of minnows, darters, sunfish and basses, fine-scaled suck-

ers, quillbacks, gizzard shad, etc., may occur. From Waverly, which is located approximately seventy-five miles downstream from Columbus, at this time there is found a very dense fish population, and this may be attributed to the combination of abundant fish food resulting from the Columbus domestic sewage, and to the concentration resulting from the driving downstream of the fish above. In winter, however, when low temperatures prevail and the stream volume is much greater, this concentration of fish below Waverly is not so pronounced and the distribution of fish is more uniform throughout its length, though even then the very susceptible species shun the waters directly below Columbus.

(2) The pollutant may affect the water adversely by introducing chemicals which unite with the free oxygen and remove it from solution, such as the discharge of coal mines, containing ferrous sulphate which unites with the oxygen dissolved in stream water to become ferric sulphate. This occurs primarily in eastern and southeastern Ohio in the mining districts.

(3) Drainage from oil fields causes the formation of a film of oil on the surface of the water which prevents the atmospheric oxygen from dissolving in the water, thereby suffocating the fish. Such conditions are not common, occurring in the oil field districts of the state, particularly in northwestern Ohio.

(4) The extremely high temperatures resulting from the use of water in transformer stations and steel mills in cooling processes are prohibitive to oxygen solution in water. Small isolated cases of the type are scattered about the state and only in northeastern Ohio, especially in the Mahoning valley, is this condition prevalent.

As a general proposition it may be stated that the detrimental effects of pollution on fish life are either temporary or more or less permanent. It may be further stated that the majority of the cases of high mortality of fish occurs when the pollutant has a sudden disastrous effect, but with the exception of the loss of fish at that time the stream is in most cases not permanently injured. The condition of the water which causes the fish to suffocate is corrected automatically by stream flow, and with the passage of a short period of time the stream may be repopulated by migration into the depopulated area of fish from other parts of the stream system. Where the harmful substance is being introduced constantly and for a prolonged period of time the injury to the fish life in the stream may be considered more or less permanent. It may also be stated that in those cases where deleterious substances are introduced which cover the stream bottom, the harmful effects persist until the substances are washed out or otherwise removed.

SCIENTIFIC MANAGEMENT—OUR FUTURE FISHERIES JOB

SETH GORDON
President, American Game Association

We have all listened attentively to a long series of learned reports and discussions at this 63rd Annual Meeting of the American Fisheries Society. Many of them have been too "deep" for us laymen, but, like good students sitting at the feet of the mighty, we have been drinking them in. Whether we understand their full significance or not, in the end we know it will be good for us.

Now with your indulgence I desire to present a few observations gleaned from my experience of twenty years in conservation work, which I hope may help all of us to focus our attention upon a few of the pressing problems ahead.

The members of this Society have labored diligently with fish cultural and research problems for sixty-three consecutive years. The federal governments, the states and provinces have accomplished much. Taken as a whole the progress recorded is of a most outstanding character. Those who have been responsible for this progress deserve our everlasting praise.

WE NEED AN AMERICAN FISH POLICY

What we need most right now is an American Game-Fish Policy, something akin to the American Game Policy, adopted in 1930. The same principles which apply to game apply to fish, but until we set up a policy by which to proceed we will continue to fumble and delay.

As in the case of game, we must get down to fundamentals. We must set up research objectives. We need stocking standards. We need stream and lake improvement standards. We need better coordination of efforts. We need more definite signboards by which to proceed.

In addition to what we can do to improve fishing in publicly-owned waters and to extend such waters as rapidly as funds permit, we must endeavor to get landowners interested in improving the fish habitat on their lands. Then the old problem of the private fish pond and the rights of the public at once arise.

How far should we go in acquiring fishing rights by lease and purchase as Connecticut has done? How far can we go in the improvement of fishing on privately-owned waters? And how far should we go toward encouraging private initiative in the production of fishing for the angler?

These are all matters upon which we can agree if we try, but we can't do it without an acceptable policy.

I hereby offer the cooperation of the American Game Association to this end. If this Society does not care to undertake such a task, I shall be glad to confer with the officers of the American Game Conference in the hope that they may see fit to put a committee, containing representatives from the Society, to work on a proposed draft for careful study before adoption, as was done in the case of the Game Policy.

Two Schools of Thought

There are those among us who hold that we have about exhausted the field of fisheries research, and that we have learned all there is to know about fish culture. They take the position that the old order of things must be changed; that all the scientists should be fired; that state and federal hatcheries should be closed, except for experimental work, and that the money saved should be used for stream and lake improvement to assure good angling, and plenty of fish for the nets of the fishermen.

Then there are those who hold that our knowledge, based upon scientific research, is after all very limited, and that the surface has merely been scratched; that we are just beginning to learn how to handle large mass production in our hatcheries and to ward off the many diseases and enemies which have beset fish culture far too long; and that we must grow more and larger fish at public expense to restock our waters.

But there is a much larger group in our midst which holds that no matter which of these schools of thought is right, the present supply of game, as well as food fishes, is entirely insufficient to meet the rapidly increasing demands, and that it is high time the scientists, the fish culturists, the administrators and the laity pool their interests for the common good.

Unfortunately there seem to be those, who sit in high places, too, who, noting these divisions of opinion among us, labor under the delusion that scientific research work is like the frosting on the cake, pretty to look at but not of much value, and that what we need is not more scientific knowledge but a more practical businesslike application of the information already in hand. This seems to be true especially of those charged with the responsibility for reducing governmental budgets.

Fisheries Trend Encouraging

Strange as it may seem, when big industries are up against it they redouble their laboratory efforts to ascertain why, and to find new and better ways to do things. When public agencies are face to face with enforced economy they put a match to the laboratory, fire the staff and use the funds to build a bigger plant, hire more laborers or to try some new experiments without a labora-

tory analysis. But that's the difference between business and government.

It takes years of consistent effort to build up a scientific staff that's worth a hoot, and only a few hours to destroy the morale and to upset the whole program.

Technically trained workers in public fisheries work are of comparatively recent origin, but they have so thoroughly demonstrated their usefulness that the trend in our public thinking is decidedly in their favor. This trend would be much more rapid if scientists would only remember to make their findings known in such simplicity that the general public could grasp the full significance of them.

Those interested in the success of our fisheries program, by and large, want facts. They are tired wasting time, a lot more money and a lot more fish in rule-of-thumb experimentation. And instead of depending wholly upon our hatcheries to turn out enough fish to fill every creel, as so many of us have done in the past, the public is beginning to appreciate the proper relation between hatcheries and stream management. Many of them are going in for stream and lake improvement with a vengeance. But more of that later.

Kinship to Agriculture

Until we put our fisheries work on the same basis as agriculture we will get nowhere. Scientific agriculture and overproduction have about ruined the farmers, but I am not anticipating that the day will ever come when the streams and lakes will be so choked with fish that one must hide behind a tree to select the right fly. No one has yet glutted the market with choice angling, even though the commercial market gets glutted to the rotting point every once in a while due to lack of cooperative management.

Our fisheries work has lagged far behind agriculture, with its thousands of scientific workers, and its millions of dollars annually devoted to research and experimentation. Yet we all realize that the future of our fish supply depends solely upon the development of a program of scientific management of our waters, and the elimination of destructive factors and practices.

We have two fine examples of what can be done in the field of scientific research and fisheries management. Unfortunately for the 7,000,000 to 10,000,000 anglers in the United States and Canada, and naturally they are my first interest, these examples are in the commercial field, a field which has its strongly entrenched, well-organized groups to battle for the things they need to protect their interest.

I refer to the manner in which our two most important commercial fisheries, the salmon runs of Alaska and the oyster beds in various parts of the country, have been stabilized and restored.

In the case of the latter, it is said that more than 50 per cent of the annual harvest is taken from managed bottoms.

Pollution and Erosion

To the fields in which the U. S. Bureau of Fisheries has attained leadership—scientific research, experimental fish culture, Great Lakes fisheries management and the salmon and oyster industries—should be added studies of other equally important problems.

Among these should be intensive study of the pollution and soil erosion problems, and their effect upon our fisheries, as well as upon the public health and recreational values involved.

We should learn how to use our water resources to better advantage through the development of extensive water farming, or agriculture, as have the older nations of Europe.

Stream pollution is the most serious menace of all, yet nowhere in our present governmental setup in the United States is there an agency with power to act in inland waters. The U. S. Public Health Service is concerned principally with epidemics. The efforts of that same agency directed in the channels of preventive activities might well improve the general health level of our people who are compelled to take their water supplies from polluted waters.

The War Department is interested in pollution only when it affects navigation, whereas its staff of experts could well afford to aid in the elimination of a menace just as deadly as war.

The Bureau of Fisheries has no power to concern itself with pollution problems, but it spends many thousands of dollars annually to raise fish for stocking purposes.

States Alone Can't Stop Pollution

The new Industrial Recovery Act gives progressive municipalities a chance to clean house through the construction of sewage treatment plants. Uncle Sam is willing to pay 30 per cent of the cost of materials and labor, and to lend the other 70 per cent if the proposition is self-liquidating and presented in the right way. Hundreds of communities are planning to take advantage of this excellent opportunity, Oregon so far leading the nation in that movement.

The various state departments are doing what they can to reduce the pollution menace, but they alone are helpless because many of the streams are interstate waters. Cooperative action has helped but something more is needed. This is a chemical engineering job for one of the federal agencies to head up.

If nothing more, the U. S. Bureau of Fisheries should at least be given funds to establish a central clearing house of information concerning the best methods for handling wastes of all kinds.

This information at present is too widely scattered, and a small staff in the Bureau of Fisheries devoted to this field would give

the clean streams movement great impetus. Such an expenditure would produce far better results than ten times the same amount spent to raise more fish.

Stream and Lake Improvement

In addition to the need for coordinated effort to eliminate pollution, we must take full advantage of what we have learned about stream and lake improvement. And we must help to head off wild ideas that are doing far more harm than good, such as the stream improvement (?) job, done on a fine trout stream this past spring by an over-enthusiastic young leader of a camp in my home state of Pennsylvania.

Up to the present time most of our information on stream and lake improvement is confined to the state of Michigan, where Doctor Hubbs and his staff have been doing such a fine job, and to private sources.

It is clearly evident that sensible improvement programs will do more for many of our streams and lakes than will intensive stocking annually, except in the case of such heavily fished waters as the streams which the states of Connecticut and New Jersey are stocking weekly during the season to meet the demands of a dense fishing population.

I frankly believe that stream and lake improvement, properly done, holds greater possibilities than most of us now realize, and that this will be one of our water farming jobs of the future. Every state and province should give this phase of our fisheries work special attention.

Here again, however, is a work which should be headed up in the U. S. Bureau of Fisheries in order that all states and others interested may avail themselves of authentic information from a central source. Without such a central agency to guide and direct, much harm may be done by over-zealous groups and individuals, and the movement will be retarded.

Refuges and Nursery Waters

Large numbers of refuges have been established for game birds and animals, but so far the refuge idea as applied to fish has not gotten very far.

Spawning and nursery waters are being set aside by certain states, and in some instances alternate sections of good fishing streams are closed to angling, but to date the studies to determine the value of such refuges and nursery waters have been inadequate.

Do they pay? Or do they not? Here is another field for intensive study by experts to determine whether this form of water management is wise.

This also is a line of study in which the U. S. Bureau of Fisheries should lead the way in making investigations, correlate the findings of the several states, and advise the public fully relative thereto.

Better Stocking Practices

In the past too many of our state and federal fish stocking programs have been 75% "political pap" and 25% good, old fashioned common sense. Why a state or province, or the federal government should maintain fish hatcheries at large expense (all borne by the licensed anglers of the states) merely to supply friends, political or otherwise, with most of the fish is beyond me..

In making this assertion I am not unmindful of the excellent judgment and sportmanship displayed by many of the recipients of such fish, but too many of our public-reared fish are going into private waters. No one can defend that practice. I firmly believe that half the number of good fish stocked intelligently, and where they benefit the public who pays for them, will produce twice as much sport for the disciples of Izaak Walton.

We are rapidly approaching the point where no public agency will stock fish until the waters have first been examined and approved by experts. And we are fast approaching the day also when all states, provinces and federal agencies will stock most of their fish with their own employes instead of shipping them to someone to help mend political fences.

Stream survey work, such as New York has been conducting so energetically, will put a stop to wasting fish, *if the recommendations of the experts are adhered to.* If not, then surveys are merely a waste of money.

Certain Hatchery Work Destructive

Certain phases of our hatchery work of the past have been most destructive. I have in mind particularly some of the hatchery operations intended to increase the commercial fish supply. On the Great Lakes, for example, the wholesale taking of fish during the spawning season has for years been justified on the flimsy excuse that it was necessary to spawn-taking for the public hatcheries devoted to commercial species, whereas if the operations of the fishermen had been regulated properly, and the fish they took during that period given a chance to reproduce naturally, the annual output would have been hundreds of times the number of fish released from the hatcheries—and the cost of the hatcheries would have been saved.

All of which is merely another way of saying that it is high time we stop wasting fish and pay more attention to the less spectacular, but immensely more profitable, job of regulating or managing our fisheries, whether they can be commercial or sport, and

give the fish in our waters a chance to produce a maximum annual increase under natural conditions.

Better Coordination Needed

Another phase of our common problem, especially from the standpoint of the angler, is better coordination of both state and federal programs. No matter how carefully streams may be surveyed, no matter how much sensible stream and lake improvement work may be done, unless there is close coordination between federal and state agencies, much waste and inefficiency, yes, even destructive work, will continue. There is no sense in deciding that a certain body of water should be stocked only with a certain species of fish, then to have some other agency stock a competitive species in the very same waters.

Much progress has been made in this direction, but there is still room for further improvement.

Curtailing Research Is Suicidal

Scientific management—water farming—is the big fisheries job of the future. We must transfer some of our former emphasis on hatchery activities to the management of our waters. By doing so we will get better results for less money, and "reduce the time between bites," as former President Hoover so aptly put it.

Notwithstanding our annual expenditure of about $5,000,000 in the United States for fish cultural work, we have failed miserably when it comes to developing a scientific research and management program which would assure the wise use of the fish so produced.

In recent years the U. S. Bureau of Fisheries has assumed a new leadership in the field of fisheries research. A staff of fine young scientists was being developed, until the staff was crippled recently in the name of enforced economy, largely because the very word "research" seemed to gall those who knew nothing about its value, and cared less.

If the present scientific personnel engaged in fisheries work is to be discharged or otherwise discouraged, the institutions of learning which have been turning out trained manpower for the fisheries field will urge their most promising young men and women to fit themselves for other fields. It must be made your business and my business to help avoid such a catastrophe.

To curtail our fisheries research, just well begun, is suicidal.

As I said in the beginning, we need an American Game-Fish Policy, in which the importance of research and the various other suggestions contained in this address are each given their proper place. Then we will have a definite yardstick by which to proceed. Without it we will continue to waste time and money.

THE SPAWNING MIGRATION OF RAINBOW TROUT

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The factors which influence the spawning migration of salmon and trout have been studied by several investigators, but there seems to be little agreement in their findings. The influence of temperature has been particularly emphasized by Ward. The conclusion that "no general rule can be devised with which to correlate the reactions of salmon to temperature, hydrogen ion concentration or oxygen, except it be that different races of salmon, through inherited characteristics, react in a different manner," has been recently reached by Foerster. It is fairly well agreed and apparently beyond controversy that all salmon and trout are especially susceptible to the influence of running water at the onset of maturity and that the chief direction-determiner during the spawning migration is the stimulus provided by a current. This reaction is in reality the fish's only compass and no matter what other influences may come into play their importance is subsidiary to the current, whether they may operate in the ocean, in the estuary, in the river or in the lake. It is in the field of these secondary influences, where a fish may choose one of two or more streams in the course of its migration, that the controversy arises.

A good opportunity for studying this problem has been afforded at Paul lake, situated near Kamloops, British Columbia. It is proposed to show in the present paper that environmental conditions, such as temperature, do play a significant part in directing the migration of the Kamloops variety of rainbow trout.

The Spawning Run at Paul Lake

Observations made on the shallows at Paul lake and the results of gill-net catches in the deeper water have contributed the information that the mature fish just prior to the spawning run in May stop feeding and move about in all directions in a random fashion, whereas the immature fish tend to move inshore and out again to deeper water within a fairly restricted feeding range. The gill-net catches have also shown that the trout select an optimum range of temperature in which to live. The older trout have a lower optimum than younger ones. Mature trout are usually found between 6° and 10° C. Hence early in the spring the mature trout are found quite near the surface.

The outlet of Paul lake is closed in early spring for storing water for irrigation so that there is no "through current" in the lake. However, the lake is particularly susceptible to the influence of the prevailing east and west winds owing to high, steep flanking hills to the north and south. At certain times the wind

action sets up definite currents in the lake as shown by "tidal" movements in the outlet bay and the depth to which warming takes place. It has been shown by Birge and Juday that wind action is most effective in the early spring when the temperature of the water is almost uniform from top to bottom. Whether the trout are influenced by the surface currents or the return under-current requires further investigation, however, the majority of them ultimately reach the east end of the lake where the two main tributaries are located. The first of these, Paul creek, has about fifty times the capacity of the second, Agnes creek, which is about three hundred yards away. The former supplied about 10,000 gallons per minute and the latter 200 gallons per minute at the height of the spawning run. Their temperature conditions were approximately the same. This year 815 trout entered Paul creek, whereas only 15 were observed in Agnes creek. There seems to be a close correspondence, therefore, between the volume of a stream and the proportion of the trout which enter it to spawn, the larger stream being the dominant spawning stream.

If the presence of the currents produced by these streams at their junction with the lake was the only factor determining the migration of this population of trout, it would be expected that after reaching the head of the lake the fish would enter the creek immediately. Apparently this is not the case. The spawning run has peculiar daily and seasonal characteristics which point to a more complicated state of affairs. The study of a typical day's run showed that the majority of the fish entered the creek during a short period in the early afternoon. A few fish ran up in the forenoon and a few in the late afternoon and evening. It was observed that the males generally preceded the females in entering the creek. During the first twelve or fourteen days of the run, corresponding to the forenoon period, only about nine fish per day entered the creek. The males always exceeded the females. Coincident with the first warm spell of weather in May the fish entered the creek in large numbers each afternoon; the average was about forty-five fish per day. The peak of the run also lasted about fourteen days. Following the peak period stragglers entered the creek for about eleven days, averaging about eight fish per day. The females exceeded the males at the end of the run, and there was a number of badly conditioned kelts.

Analysis of the Factors Affecting the Run

In order to determine if temperature exerted any influence on the run a close check was kept this year (1933) on the temperature of Paul creek and a series of temperatures at different depths in the lake was taken during the run. For the purpose of analyzing and discussing the effect of temperature, the spawning run may be conveniently divided into three sections as described above.

(I.) The early phase of the run.

The ice disappeared from Paul lake about April 20. At first the temperature of the water was fairly uniform at 4° C. However, the surface soon began to warm and by the time the spawning run commenced (April 26) the upper layer had reached 6° C. Snow and ice lingered in the vicinity of the creek for some time because it is sheltered by a considerable forest, consequently the creek temperature did not rise above 5° C. even at the warmest part of the day. The volume of the creek was at first small, remaining at its low winter level until about the first of May when the snow on higher ground and the ice on Pinantan lake at the head of Paul creek began to melt. The few fish which entered the creek during this period probably located the current accidentally by swimming at random across the shallows. Since the males are apparently more active in their random movements than the females their chances of coming under the influence of the creek are greater, hence they outnumbered the females. It should be noted that the fish passed from the warmer lake water into the colder creek water, showing that where there is no choice of currents, temperature is to a certain extent a secondary consideration. During the second week of the early phase of the run the volume of the creek increased considerably. On May 2 it was delivering approximately ten times the volume that it was on April 26. The increase in volume, however, was attended by only a slight increase in the number of migrants. A study of the temperature relations which existed between the creek and the lake on May 2 showed the following: The creek warmed up from 3.8° C. at 9 A. M. to 5.2° C. about 2 P. M. Since two bodies of freshwater of the same temperature are presumably of the same density, the creek water flowed out into the lake toward water of the same temperature. A cross-section of the temperature of the lake on May 2 showed that the creek, early in the morning, spread out in a very thin layer over its delta following the bottom downward. The slight degree of warming which it underwent during the day only served to dissipate its current over an even wider range of bottom. Since the main point seems to be the establishment of a well-defined connection between the current of the creek and the upper stratum of the lake in which the mature trout are located, it will be observed that this possibility is slight as long as the creek remains cold and warms but little during the day.

(II.) The peak phase of the run.

On May 10 the weather cleared; it was quite hot in the afternoon and fifty trout entered the creek between 11 A. M. and 5 P. M. The temperature of the creek rose from 4.2° C. at 9 A. M. to 7.1° C. at 4 P. M. The temperature relations showed that the creek water began to pour into the optimum level for the trout about 1 P. M. and the peak of the run occurred between 2 P. M.

and 3:30 P. M. The slackening of the run in the late afternoon may have been due to an exhaustion of the supply of migrants in the immediate vicinity of the creek. The next day, May 11, there was a considerable increase in the volume of the creek and the temperature relations were the same but only forty-one fish entered the creek. Nevertheless there is a general relationship which exists between the size of each day's run and the noon temperature of the creek during the whole season. When plotted on graph paper the cumulative curve for the number of trout in the creek parallels the noon day temperature curve for the creek. The daily run was small as long as the noon temperature remained below 6° C. and the peak of the run occurred between days when the creek had noon temperatures from 6° C. to 10° C.

(III.) The "straggler" phase of the run.

After the main part of the run had entered the creek, there were a few stragglers. These fish may run late as a result of a number of influences. They may be late in maturing; young fish and badly conditioned kelts, particularly females, were characteristic of this phase of the run. They may come from the far end of the lake and distance may therefore be a factor in the delay. It is interesting to note, however, that the straggler phase occurred after the noon temperatures in the creek had reached 10° C. While it is quite probable that the slackening of the run was due to an exhaustion of the supply of mature fish in the lake, the temperature relations showed that the creek water ran out at a fairly high level. It may thus pass over the optimum level and completely disrupt the current system, so that the process of accidental location may again become operative. The fact that "rawners" (unspawned fish) were caught in the lake in June and July seems to provide evidence for the disjunction of the current system.

The Choice of Two Currents

In the description of the spawning run it was shown that where conditions were equally favorable, the proportion of trout which entered a stream was dependent on its attracting powers, i. e. volume. Paul creek, at a point midway between Paul and Pinantan lakes where it is joined by Lloyd's creek, affords an example of the junction of two currents of water which apparently are not equally favorable. Lloyd's creek is usually larger than Paul creek. It is spring fed, having no lakes at its source, and consequently at the time of the spawning run is 3° to 4° C. colder than Paul creek above the junction which has been warmed at the surface of Pinantan lake. During the run Lloyd's creek invariably remained below 6° C., that is, below the optimum temperature. The spawning fish kept to the mainstream preferring the warmer to the colder current.

It was also observed that once the trout had ascended Paul creek a short distance above the lake, they remained in the stream in

spite of adverse temperature conditions. However a frosty night accompanied by a sharp decrease in temperature retarded their spawning activity and their upward migration but on the other hand a rise in temperature increased their movements. Trout handled at the counting fence on cold mornings were far less active than those handled when it was warmer.

Conclusions

While the conclusions drawn from the foregoing observations require a more thorough corroboration before the details can be fully accepted, it does seem possible to formulate certain general rules into a working hypothesis for the migration of trout apart from their racial characteristics. Current stimuli provide the dominating influence on migration, but where two streams are equally favorable, the number of trout which enter each is determined by their proportionate volumes. As far as temperature is concerned if a choice between two streams, not equally favorable, is presented, the trout will choose the one nearer the optimum. Furthermore it seems likely from the evidence supplied by Ward and Foerster that this hypothesis can be applied generally to salmon as well as trout.

THE INVESTIGATION AND REGULATION OF THE PACIFIC HALIBUT FISHERY

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The halibut fishery of the North Pacific Ocean is comparatively young, having originated in 1888, soon after an eastern market was opened up by the completion of the first railway between the east and west coasts of the United States. From the beginning it has been an international deep sea fishery, the nationals of both Canada and the United States engaging in it, principally in extra-territorial waters.

From a small fishery near Cape Flattery, at the entrance of the Strait of San Juan de Fuca, it expanded rapidly in the protected waters and by 1910 extended some seven hundred miles northward to Cape Spencer in Southeastern Alaska. Subsequent expansion has extended the fishery both south and north and to the open sea, and for some years fishing has been conducted on banks throughout the known range of the species on the American side of the Pacific, from northern California to Bering Sea, a distance of over two thousand miles. The catch is worth, in normal times, between six and seven million dollars annually to the fishermen.

The history of the halibut fishery has been similar to that of many other great modern fisheries. Due to expanding markets and increasing prices, new and more efficient vessels have been constantly added to the fleet. Taking advantage of each improvement in type of construction, in power and in methods of fishing, these vessels have been able to extend their operations to more and more distant banks, as the more accessible ones offered less profitable fishing.

Early in the fishery it was realized that the stock of halibut on the older banks was being rapidly reduced, but no attention was paid to this, as the supply from new banks seemed inexhaustible. In 1914 for the first time, control of the fishery was urged, not however for the purpose of conserving the supply of fish but to curtail production. Depletion of the older banks was recognized but not stressed. Shortly thereafter a winter closed season was specifically proposed by both fishermen and dealers, as eliminating a dangerous season when the spawning fish caught were of poor quality and as offering a period during which stocks of frozen fish could be sold. Conservation of the supply was at first incidental, it being urged that the closure would conserve the fish. As time went on, due primarily to three reports by the British Columbia Commissioner of Fisheries (Thompson, 1916 and 1917) which for the first time proved conclusively the decline in the abundance of halibut on the older banks and in other ways showed the need of

regulation, conservation was stressed more and more as the object of proposed regulations.

Considering the international nature of the fishery, control had to be by international agreement. In the succeeding years various attempts at international action failed, due to the inclusion of various controversial matters within the proposed treaties, and it was not until 1924 that a treaty for the preservation of the halibut fishery of the Northern Pacific Ocean and Bering Sea was concluded between the United States and Canada. This treaty was the first ever to become effective for the conservation of a depleted deep sea fishery, and it established a precedent for cooperative international control of sea fisheries.

The treaty provided for an entire cessation of halibut fishing for three months of each year and for the appointment of an International Fisheries Commisison, to consist of two commissioners from each country. The duties of the Commission were to make recommendations regarding any desirable changes in the closed season, to make a thorough investigation into the life-history of the Pacific halibut, to report on the same to the two Governments, and to make recommendations as to the regulation of the fishery for its preservation and development.

Following their appointment, the commissioners secured the services of a competent scientific staff headed by a director with not only the necessary ability and training but also previous experience with the halibut fishery. In addition they arranged for the appointment of an advisory scientific council of experienced biological and fisheries scientists with whom not only they but also the director of investigations could consult from time to time regarding the plan of investigations.

The investigations of the Commission, though scientific in character, have been carried out along practical lines with close adherence to facts and avoidance of unsupported theory. They were planned to determine the actual condition of the fishery at the present time and to show the history of its trend to the present condition. They were designed to supply the information necessary for determination of the type and amount of regulation which must be applied to save and build up the fishery. And provision has been made for closely following and analyzing the results of these regulations, which must in such a pioneer attempt be subject to revision as results are obtained and as conditions are thereby changed in the fishery. The investigations have been both biological and statistical, as only by a combination of the two is it possible to determine what has been and is happening to the fishery and to the species.

The statistics of the fishery have formed an indispensible part of the facts gathered. Those collected include not only the ordinary statistics of landings but also catch by bank of origin and unit of fishing effort. The collection and analysis of the latter, which can

only be obtained from the log records of the captains of the various vessels, has been a very laborious task, but the vital information it gives can be obtained in no other way. From it the changes in abundance by bank and season have been determined as far back as 1906, an excellent basis for the work to be done.

Of equal importance have been the biological studies. These have been limited to those phases of the life history that have a specific bearing on the problems of determining the condition and needs of the fishery and of devising methods for rehabilitation of the stock. They have made it necessary for investigators to spend long periods of time at sea, on fishing vessels under cramped and often dangerous conditions. Indeed one cruise ended in shipwreck in which loss of life was avoided only through remarkable good fortune. Spawning, the drift of pelagic eggs and larvae, the rate of growth, the migrations of the adults, and the existence of separate geographic races have all been studied. Many facts of fundamental importance have been established and applied to the solution of the problems confronting the Commission and many others are under investigation.

The first major problem to be solved by the Commission was that of measuring the extent of depletion of the populations on the different banks to determine their individual needs. At the outset it was clear that the fishery south of Cape Spencer was badly depleted. The total catch had declined, though much more fishing was being done. Moreover the small size of fish landed indicated that spawners were very scarce there.

The statistical studies showed that the abundance of halibut in Hecate Strait, the most productive of the older grounds, had fallen in 20 years to between 15 and 20 per cent. of its earlier abundance and was continuing to fall. The intensity of the fishery on those grounds had more than doubled during the period in question yet the total catch was only 40 per cent. of those of earlier years. It required from 5 to 6 times as much fishing to catch a given quantity of fish. On Portlock Bank, one of the most productive of the newer western grounds, the fall in abundance amounted to 40 per cent. in 4 years, and was continuing. These two grounds are typical of the southern and western regions. The level of abundance on the more recently exploited western grounds was higher than on the long exploited southern grounds but was declining much more rapidly.

The biological studies proved that the halibut is a slow growing fish, the majority not entering the fishery until they are seven or eight years of age and not reaching maturity till about their 12th year on the average. The migrations and racial studies of the adults indicated that the populations of the western and southern grounds are distinct biological units and must be treated independently. The investigations also showed that the western grounds still had sufficient spawners to

maintain their populations but that on the southern grounds relatively few halibut reached maturity, due to the intensity of the fishery.

The findings convinced the Commission that the halibut on neither the southern nor western banks could stand the intensity of fishing to which they were being subjected, that the survival of the fishery on the southern grounds was seriously endangered and that the fishery on the western grounds was rapidly approaching a similar condition. They indicated that additional regulation was necessary for its preservation. The Commission therefore, in fulfillment of its duties as defined in the treaty, prepared a report showing the condition of the fishery and recommending certain additional measures of conservation.

In its choice of a method of regulation, the Commission carefully considered the merits and demerits of the various methods in use. It finally decided in favor of the most direct one, as being most satisfactory from both scientific and administrative viewpoints and as being the least objectionable to the fishermen. It recommended the limitation of the catch in the different sections of the coast, according to their individual needs and the annual reduction of the limits until decline in each section should cease. As supplementary restrictions, it approved the continuance of a winter closed season during the spawning period, and the closure of grounds populated predominantly by very young immature halibut, and the prevention of the use of any fishing gear deemed unduly destructive of small unmarketable fish. As an aid to regulation it proposed the licensing of all but the smallest vessels for the purposes of the treaty including the collection of compulsory statistical returns. These recommendations were submitted to the Governments of the United States and Canada, early in 1928, and resulted in the conclusion during 1930 of a new treaty, by which power was given the Commission to make all the proposed regulations effective.

The new regulations went into effect at the beginning of 1932. They consist of the designation of areas and the setting of a limit for each; the current collection and tabulation of statistical returns of halibut vessels over 5 tons net, showing the origin of the fish caught; and the closure of each area to fishing as its limit is reached. In addition two nursery areas are closed to fishing at all times. In no case have the limits set been sufficient to keep the banks open longer than had previously been the case. These regulations are determined upon in the fall after public hearings and announced before the next fishing season.

Throughout its existence the Commission has maintained close contact with the fishing industry. Public hearings, formal meetings with representatives of the various branches of the industry, and informal meetings with various interested individuals and committees have produced a spirit of cooperation in the solution of the problems of both the Commission and the trade. The meetings and hearings have served the purpose of acquainting the industry with the scientific find-

ings of the Commission and of supplying the Commission with information pertinent to regulation.

Past experience in the regulation of other marine fisheries offers no information by which it is possible to predict the effect of a regulation on this fishery and through it upon the halibut species. Each regulation must be regarded as an experiment and be given the same careful observation accorded any other experiment. The fishery is in a state of constant change, and its successful regulation therefore involves a system of statistical and biological observation. Such a system was installed by the Commission in anticipation of active regulation and must be continued as long as the fishery is under control. It provides the means by which old regulations may be judged and the foundation on which new ones must be based.

The first beneficial effects of regulation have already appeared. The Commission has shown by statistical research that due to the decrease in the intensity of the fishing, the amount of halibut on the banks has begun to increase. The increase is not due to a greater number of fish through prior increase in spawning but to the survival in greater numbers and the additional growth of fish already in existence at the time the measures went into effect. Such an increase must precede, not follow, greater production of spawn. The commercially available stock of halibut on the banks must survive in greater numbers to make mature fish more numerous, and the observed increase is the first step to increased spawning. An increase in spawning and a later increase in young fish at the age of five of six years, necessary to put the present temporary improvement of the stock on a permanent basis, will be the logical consequences, and the Commission will make every effort to properly observe and record the results expected.

In the meantime there may be adverse changes due to the recent very intensive fishing for the larger mature halibut in southern waters, which during 1926 and 1927 began to take a heavy toll of the remnant of spawning stock. The recent regulations adopted have greatly reduced this fishing, but the stock has nevertheless been already sharply reduced, as shown by the diminished catches made on the spawning grounds.

The ultimate aim of the Commission is to determine the most profitable extent of regulation. The results of the investigation so far indicate that the abundance of the stocks of fish on many banks has been reduced far below the point of maximum productiveness, the point where the greatest annual additions to the stocks took place and where consequently the greatest possible catch could be taken without injury to the stock. By regulating the fishery more severely now the Commission hopes to raise the abundance of fish to a point where a greater annual catch can be taken without injury to the supply. Considerable data relating to the subject have already been collected, and the continued observation of the effects of regulation will add more of even greater value.

This is a rather bare recital of statistical facts but every phase of regulation has necessitated biological research of the most interesting character. The collection and analysis of the statistics themselves are based on a knowledge of just what sections of the banks constitute logical units, as decided by marking experiments to show migration and by the differentiation of races through physical characteristics. In these marking experiments thousands of fish have been captured, had metal marks attached to their opercles, and been released to wander unrestrained till recaptured by the commercial fleet. The returns indicate not merely how far the fish have travelled but what percentage the fishery retakes. Marks placed in 1925 occasionally are retaken at present, after eight years of deep sea exploration, and it is evident that a halibut is fortunate to be able to survive that long, because of the high percentage taken by the fleet, exceeding 30 per cent. as a whole, and in one locality 70 per cent.

The determination of the age of many fish, by counting the rings on their otoliths, has been necessary to determine the nature of the stock on the different banks, and to tell when and how increases in abundance must appear as the result of regulation. Spawning grounds and nurseries must be defined by determination of the age of the fish taken there before they can be closed. Age studies must be continued during the process of rehabilitating the fishery, to properly understand the changes taking place.

The discovery and description of all stages of development of the floating halibut eggs and larvae, which the much more extensive oceanographic work in the Atlantic has failed to do, has been a necessary preliminary to the determination by means of plankton nets of the abundance of spawn on the different banks. This has been successfully completed and the first rough quantitative determinations of the amount of spawning have been made, revealing that spawning is almost lacking on the badly depleted southern grounds. As long as regulation is continued, more exact studies of the same kind will be essential in determining the need for and the results of regulation in any particular area, because the relative success or failure of spawning is a vital consideration in regulation.

In conclusion it should be stated that due to the success of its investigations and the already apparent response of the stocks to regulations, the Commission is confident that as time goes on it can determine the most productive level of abundance for each bank, bring the abundance of stock to that point, and keep it there. This is the ultimate aim of all fisheries research.

SOME IMPORTANT PRINCIPLES OF FISH CONSERVATION

DR. RAYMOND C. OSBURN
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For a generation now we have heard more or less about the subject of conservation, ever since Theodore Roosevelt called our attention so forcibly to the "conservation of our natural resources." With increasing vigor the slogan has been raised as we have seen these resources dwindling away and little or nothing being done about it in many quarters. The term "conservation" has become one of the stock promises of political aspirants, though it is very doubtful if most of them have any very clear conception of the meaning of the term, let alone its applications. To them it is just another of those things which some people want, which is easy to promise before election and just as easy to forget about afterward; it is a big word and sounds well in a pre-election speech.

The anglers and hunters, especially the older ones who can remember the abundance of fish and game in their youthful days, have done more than any other group to bring the matter of conservation before the public, and for nearly thirty years, I have heard the subject discussed in the meetings of this organization. Our local society, the Central-Ohio Anglers and Hunters Club, has taken a very active part in urging legislation and presenting constructive measures before the legislature, some of which I am glad to say have been put into effect. Last winter this Club thought it might be well to issue a small pamphlet or folder explaining the meaning, scope and purposes of conservation in its various phases of water, forests, land, wild life and public health, and I was requested to write a general definition in less than 300 words, to be followed by statements from others concerning the various phases of conservation. My statement, which is well below the 300 word limit, is as follows and you can find as much fault with it as you like:

CONSERVATION

Conservation is the proper management of Natural Resources.

Conservation includes the present use of such resources, their preservation for future use and, in cases of partial or total depletion, their restoration where possible.

Conservation covers a very broad field: the quality, quantity and control of water supply; soil fertility and erosion; forest restoration, preservation and culture; minerals; public health; restoration and preservation of fish, game and other wild life; protection of scenic and picturesque regions, etc. Some of these have to do with material wealth, some with productivity, and others with the health, happiness and contentment of the people.

Conservation often presents very complex situations. Thus, in clearing land for maximum crop acreage, many forests have been needlessly sacrificed, leaving little timber standing. This results in the rapid run-off of water and contributes to the increase of both floods and droughts; exposure of the soil renders it susceptible to erosion, destroying the fertility of farms; while interference with the natural abodes of fish, animals and birds has caused their partial or total extinction. Wastes from mines, oil and gas properties, factories and municipalities have been discharged into streams and lakes, necessitating costly treatment operations to fit the water for public use, rendering it unfit for recreational purposes, creating a menace to public health, and destroying fish and game and their food supplies.

Conservation has been neglected, and our present conditions are due to ignorance, carelessness, ruthlessness and lack of foresight. The destruction of our birthright is not the part of wisdom, and the thinking man will have an eye to the future as well as the present.

Conservation is a matter of good husbandry applied to all natural resources. It concerns every citizen, for upon it depends the future happiness and welfare of humanity.

Since this is a fisheries society I would like to limit my remarks to the conservation of fish, but how is this to be accomplished when so many different other things are linked so closely with it? How is one to discuss fish conservation without considering the question of reforestation, when we see our streams in many of the older parts of the country constantly dwindling in the dryer seasons and rising higher in destructive floods with each successive year, to the destruction of fish life, as well as other resources. Forest fires are a menace to fish as well as to other wild life, not only from the heat evolved, but especially since the ash washed into the streams may cause the death of all the aquatic organisms.

Must we eliminate soil erosion, which increasingly silts up our streams with the ensuing destruction of fish and fish food? Should we leave out the so-called improvement projects, which frequently wind up as merely destruction projects, which are promoted by companies that want the job and which are "put over" on an unsuspecting public with all the "ballyhoo" of high pressure salesmanship, regardless of the ultimate consequences? And can we fail to take into consideration the fouling of the water, absolutely essential to all life, by industry and by a civilization which even yet has not advanced in many places beyond making open sewers of our streams for the reception of all their filth.

All of these things and many others must be taken into account in any constructive policy of conservation of fish life, without considering their relation to other things and their individual im-

portance in the welfare of mankind. But my time is necessarily limited and I desire to call your attention to some of the things which can be done at present in any well organized state conservation department, or even in a fish and game division.

The first and most important item is to know all of your waters in every detail, for upon this will depend your whole policy of fish conservation. This means a scientific study or survey including stream flow, especially at low water, for it is useless to plant fish in streams and ponds that dry up too much in seasons of drought, however good they may appear to be at other seasons. It includes pollution of all sorts, especially mining and industrial wastes, containing substances actively poisonous to fishes and their food organisms, for these are the worst of all and it is useless to place fish in such waters even though these wastes are only periodic or occasional. In one beautiful little river with which I am well acquainted the supposedly accidental outbreak of an industrial waste killed everything for 25 miles. It took that river several years to recover fully and it would have been useless for at least a year to stock that stream even with breeders only, as the natural food was so limited that fish would have starved or migrated. Even sewage pollution, though not often directly poisonous, may deplete the oxygen to such an extent that fishes are destroyed and this should be studied at the time of greatest concentration, namely in the season of lowest water and highest temperature, for these usually fall together. Low water means more concentration of sewage and high temperature means more bacterial activity, less oxygen and more carbon dioxide. In other words, for any proper fish planting policy we must know the water at its worst, for that is a condition our fish must undergo, usually every season, especially in these days of highly intermittent stream flow.

Also it is just as important that all the chemical contents of the natural waters should be known, including acidity and alkalinity (hydrogen-ion concentration), dissolved oxygen and carbon dioxide and other chemicals in solution, for upon these depend the natural productivity of the water and the kinds of fish that will live in it. Practically all of our unpolluted waters are sufficiently oxygenated for fishes to live, though there are times when the rapid decay of heavy vegetation in ponds will cause the death of fish through the depletion of oxygen. But low oxygen may be a controlling factor in the reproduction of food organisms and within limits there is a ratio of oxygen to the production of fish food. The hydrogen-ion content of the water (acidity or alkalinity, in general terms) is very important if at all extreme in either direction, for while fishes may become gradually acclimated and are found in both acid and alkaline waters, if not too ex-

treme, the transfer of fish from one to the other usually means their death in a short time.

Of course, the idea is familiar enough to us, but not to many others, that waters must be impounded to a greatly increased extent if we are to continue to furnish fishing to our increasing populations, as well as to maintain the water table and the evaporation rate. The rearing of dams to impound waters for these combined purposes should be a part of every conservation program.

Temperature is another factor which must be known, as in many parts of the country some waters become too warm for certain species of fish, while others may never become warm enough for certain other species to thrive properly. Especially in the transfer of breeders these factors should be known, since any abrupt change in temperature or the chemical content of the water may result in the loss of the eggs or the failure of the fish to spawn. Naturally it takes the time of skilled scientific assistants to collect such data, since it involves a knowledge of chemical methods in the study of the dissolved content of the water, and this work should be followed with some regularity to keep track of any changes that may take place as a result of our rapidly changing civilization. The results, however, are well worth all the time and money necessary to achieve them.

Another series of data necessary to avoid the loss of time, money and fish has to do with ecology, the natural relation of fishes to their environment and distribution. One body of water may appear as good as another to you, but not to a fish who has to live in it, and I presume more effort has been wasted by planting fish in unsuitable environments than in any other way. I know that in this state there has been in the past a great deal of wasted effort in planting fish in waters not suitable for them, and if any other state or the federal government has always met this issue in the past I am not aware of it. Here in Ohio, in past years, through ignorance of fish ecology, thousands of yellow perch have been planted in the waters of the southern part of the state with no permanent results whatever and I presume they would still be trying it but for the knowledge we now have. Similarly large-mouth bass have been planted in large numbers in the open rivers of the state and small-mouth in the warm and weedy shallow lakes, ponds and reservoirs, where they will not stay, or if unable to get away they gradually disappear. One should not expect to grow reindeer moss in Louisiana, nor sugar cane in the Arctic Circle. Of course experiments without previous knowledge sometimes work. Years ago some white bass (Lepibema chrysops) were accidentally introduced into Buckeye Lake in this state along with other fish from Lake Erie, and they multiplied enormously. The carp was introduced into this country without

previous knowledge of its special ecology and the Lord knows they have done well enough. On the other hand many thousands of both the large-mouth and small-mouth bass have been planted in the lower tributaries of the Ohio River in this state and the fact remains that the spotted bass, which never received any attention in the way of cultivation, is the dominant bass in all of those streams, because it is better suited to them. We are trying an experiment now in the planting of various members of the trout family in certain cooler, rapid streams of this state, but we are doing it with a fairly complete knowledge of the nature of the water, its temperature range, chemical content, flow, and the available food, as well as of the results of experiments elsewhere, and we realized that we were about on the border line of safety.

Another real need is that of educating the general public and our legislators as to the importance of conservation and the need of continuing surveys of water conditions. At present they do not know, most of them at least, what it means and they have no idea of the time and labor required to obtain a proper knowledge of the situation. Legislators are as uninformed as the average man and often appear to think that the conservation division is just another opportunity for the appointmnet of their political henchmen. Fortunately we seem to have outgrown this condition in Ohio to a great extent, owing largely to the efforts of our sportsmen's associations. Certainly there is no place in the work of the state that calls for more scientific knowledge and field experience than the conservation work.

As a result of this ignorance there is often improper pressure brought to bear on the division of conservation. For example, some of Senator Jones' constituents think they want large-mouth bass or yellow perch or maybe muskallunge planted in Mill Creek, however unsuitable its waters may be for this particular fish, and they go after him about it. He, of course, knows no more about it than they do, but he has influence and he makes his request to the director of conservation. Now there is only one thing to be done about it and that is to inform the worthy senator that it cannot be done, that rock bass and catfish are suitable and will be sent. The people may be put out about it, but the conservation department is due to get it any way, for if unsuitable fish are sent they will not continue to inhabit Mill Creek and the department will then get the blame for that. It is better to stand firmly for what you know to be right.

It is astonishing how little many intelligent people know about fish, even the commoner ones. I have been out fishing this summer with four college professors who did not know a black bass from a sheepshead and who would have taken young, of eight or

nine inches, with no thought of breaking the law. Of course the more expert angler usually knows.

Then there is the ignorance of the live bait fisherman concerning the young of suitable size for bait and too often he thinks every small fish a minnow. I have often seen young perch and bass in minnow buckets, ready to be sacrificed before they grow up. On the whole I have found people very ready to be instructed, and I believe that is the usual experience. The department of conservation is the proper center for such education. Illustrated lectures are generally in demand by the sportsmen's clubs, and little, "know-your-fish" pamphlets, properly illustrated and written in simple, non-technical language are probably the best source of such information and should be spread broadcast. Especially all the schools should have them. Some time the principles of conservation may be taught in the public schools, but I fear that is a good way off yet. The Boy Scouts are the finest material for this training and it will probably go farther and stick better there than any where else. Certainly we can not reach our final goal in conservation until there is more general education along this line.

Then there are the problems of size and catch limits that must be solved for the various kinds of fish in each locality and this should be made to include commercial fish if the industry is to survive. Also the problems of food, methods of rearing and time of distribution best suited to the species and region must be included in any proper study of propagation work. The closing of waters for breeding sanctuaries, and the growing problem of the depletion of natural food by the live bait dealers also vary with time and place.

This highly intricate and complicated problem of the conservation of our natural resources must be solved eventually in all of its aspects. That it is not impossible of solution is shown by the progress we have made in fish conservation in recent years and in certain states, for in spite of continued deforestation, increased erosion, lowering of water table, pollution, increased angling, and all the other deterrent conditions, there are more fish than there were ten years ago wherever conservation has had a chance to work. For the most part the problems are such that only the trained and experienced scientific man can aid in their solution. In Ohio we have been carrying on such scientific work since 1920 and the results are evident in the shaping of our conservation policies, in our improved stocking methods, our more productive hatcheries, our knowledge of the ecology and natural distribution of our various fish species, and all that makes for the betterment of the work. The practical scientist is essential to this work and it can only progress with his aid.

Supplementing his paper, Dr. Osburn said:

This summer I had the experience of going fishing with four different college professors who did not know a black bass from a sheepshead, and they would have taken eight or nine-inch young bass without realizing that they were breaking the law. I gave each one of these men a little special session in the laboratory and demonstrated some of these things to them. Expert anglers, of course, know.

THE STATUS OF OUR BLACK BASS WORK

HARRY B. HAWES
Washington, D. C.

The President: I would like to take this opportunity to introduce former Senator Hawes, who, I observe, has just come into the room. It is a pleasure to have Senator Hawes with us, and we shall be glad to hear from him.

Senator Hawes: Mr. Chairman, I am always impressed when I attempt to address men who know so much more about a subject than I do. The thought of conservation starts with the fisherman. Most boys are fishermen before they become hunters, and their first contact with wildlife is usually associated with a cane pole, a cork and a worm. I served on the Fish and Game Committee of my legislature, and it was one of the most delightful experiences of my life, because I came in contact on that comittee with men who understood their subject. Later, coming to Congress and then to the Senate, I found that in both houses we had sympathetic members, but so busy with other problems, so busy with patronage and economics, that it was difficult to interest them. Once their interest was aroused there was no problem at all, because they were sympathetic.

Tomorrow I address the other section of this meeting at some length on the general subject of conservation, and will then go into the question of federal and state control. But it seems I am now to talk about the black bass. I wrote a book on that subject, and after I had finished it my title became "My Friend, the Black Bass." We find the black bass in thirty-one states—more widely distributed than any other fresh water fish, but he is the hardest to propagate. As you all know, you can secure the sperm of the female of the trout, muskellunge, pike or pickerel, and, properly fertilized, put it in a can and send it to any portion of the United States. But Mr. Black Bass seems to be a sort of family man. Experiments have been made for years to try to treat him in the same way that we do these other fishes, and it cannot be done. He has his mate, he builds his nest—or his wife does—and there they have a continuous fight against all the predators in the waters, particularly with the German carp, this miserable thing that has been imported into our country and is now destroying not only our fresh water fish but the food for ducks in certain sections of our country.

We have found that in many states there was a prohibition against the commercial sale of black bass, but in the enforcement of that law the state was always handicapped because black bass could be sent in from an adjoining state and sold on the open market. Whenever one of the commercial dealers was arrested

he would say that the fish came from a nearby state. Take my state of Missouri, for instance: A dealer was found with black bass, and his answer and his evidence was that these black bass came from Reelfoot Lake in Tennessee. It was simply impossible to enforce the will of the state, so we conceived the idea of passing a national law which would prohibit the commercial sale of black bass in a state where there was a law prohibiting their sale. Then the question of enforcement came up. What with prohibition and other things, the consequent congestion of the dockets of the district courts and the fact that the black bass seemed to be such a small item in relation to counterfeiting, bootlegging and so forth, we found we had to have some branch of government which would give its entire time to the enforcement of that law, to prepare the cases and hand them to the United States district attorneys. We asked for an appropriation of $25,000, and we got it. This last year we had great difficulty in getting any money, It is no reflection on our government; the national situation called for economy in the states and economy in the nation. Finally that appropriation was withdrawn, and the reason for its withdrawal is one of the comedies of Washington. The dear ladies of our country have what they call a Maternity Bill, which is an appropriation from the national government, to be matched by state governments, to give instruction in the care of expectant mothers and babies. Their appropriation was cut, and someone told them that the money had been appropriated for black bass; so that the dear ladies raised the issue of babies vs. black bass—which will you save? It frightened some of our Congressmen and Senators—a very unfortunate issue to be raised back home, babies or black bass—and they cut out the appropriation. But peristent effort on the part of such men as Seth Gordon and the leaders of the Izaak Walton League and others when the general appropriation bill came along resulted in the appropriation being put back. Then they knocked it out again—it was like Finnegan, off again and on again. But we believe now we have the money—at least $13,000—to see if we cannot in certain districts at least enforce this black bass law. Talbott Denmead, who had charge of this, has built up a contact organization with state game and fish commissioners. This is purely voluntary; it is one of those instances of cooperation where the public is involved and the state commissioners ready to respond.

I passed the Upper Mississippi Wild Life Refuge Bill when I was in the Congress, which, as you know, covers some three hundred miles of the upper Mississippi River. The men in charge of that district will tell you what work they have done in the saving of fish, the propagation of fish and the distribution of the bass. I will tell you a story—provided the reporter will omit the cuss words and still make it interesting. I have a very dear

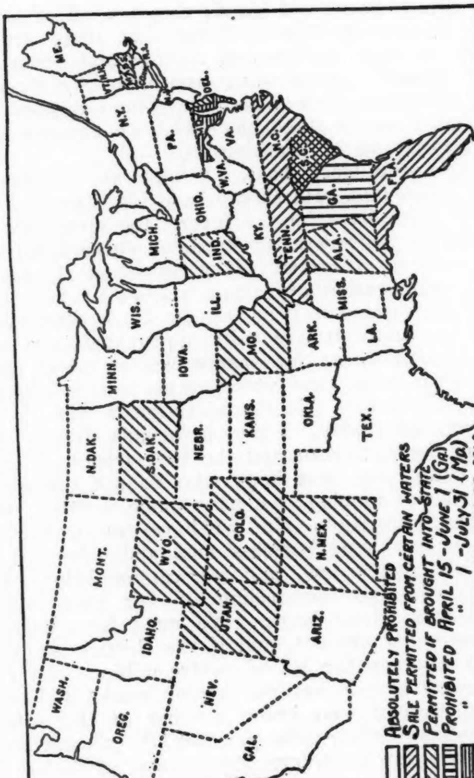
friend who served with me in the Senate, a gentleman named Brussard, from Louisiana. Like all men of French ancestry, his mind runs to food, and delicious food, and how it should be cooked. Another friend of mine, Senator Walsh, was giving a dinner to Peter Gary, who was retiring from the Senate. Edwin and I were on our way to the dinner—both of us had had a few drinks. Edwin said: "I say, Harry, what do you think we are going to have to eat tonight?" "Well," I said, "we are going out in the country; I expect it will be a country dinner,"—there were eighteen senators going. "You know, Harry," said he, "my favorite food is fresh water black bass, and I can't buy them any more. I sent the servants down and they couldn't buy them in Washington; then I sent Mamma down"—meaning his wife—"and she couldn't get any; so finally I went down myself, but they don't sell them any more in the District of Columbia." He said: "Do you know, Harry, somebody passed a bill prohibiting the sale of black bass, and you have to help me repeal it, because I can't buy any." I remarked what an outrage it was—and of course it was my bill, as you know. It shows that it worked.

Now, drifting away from the subject of black bass, you all know Henry O'Malley. You have been associated with him for many years, and of course it was a shock to you when a change was made. But I have talked to Commissioner Bell and I find that he is thoroughly sympathetic with the objects which you gentlemen here have in mind, so that you are going to have his active cooperation. But there is great confusion in Washington—I was there during the world war, and the confusion is greater in Washington today than it was at that time. The thing has not settled down; it has not got into its normal stride as yet, and we conservationists have to keep at it until we know that the men to whom we tell our story will listen to it, that it won't go in one ear and out the other. That time is rapidly approaching. We have plans for a great conference there when Congress meets. Our trouble in conservation does not arise from the men who understand it; the trouble is we have a lot of cranks, sentimentalists, who do not pay any of the bills either for fish or for game and who constantly interfere in practical programs. They are great publicity people; they are great fellows for writing to the newspapers, and the newspapers do not go thoroughly into the subject and they print their letters—that is a matter I am going to discuss tomorrow.

Mr. Chairman: I have always believed that there is a bond between the fishermen and the hunters which should become closer each year. It has been my observation that the fisherman who starts in after the spawning season and fishes for four or five months, when the fishing season closes is the man who picks up his gun and becomes a hunter. The two sports are related;

they appeal to the same red blood; they are all of the same kind of people. If we can bring it home that there are six million men and women who buy hunting licenses and seven million who buy fishing licenses, representing approximately twenty-five per cent of our adult population, and they stand together, the sentimentalists will have to stand aside and we can get any kind of legislation we require in Washington.

Returning to the black bass. I hope all you commissioners will be friendly to him. He should have his chance. In the great programs which we have for the future, the sanctuaries for ducks to be paid for by the federal government, there is no reason why sanctuaries built for the duck flight cannot at the same time be used for the propagation of certain species of fish—the two go together. We are going to bring up the Duck Stamp Bill and try to pass it. We think it will raise approximately a million dollars a year, to be spent for sanctuaries in marsh areas. Now, marsh areas mean water, and water means fish, so tomorrow I am going to talk about that. In the meantime I want to thank you for inviting me here today. I have a formula that the best friend of the fish is the fisherman and the best friend of game is the hunter. Of course we have hogs who do not respect any legal limits as to size or number; we have game outlaws who respect neither law nor regulation. But we have our penitentiaries with bankers and lawyers and business men and others—full of men who have violated the law, and we cannot help that. But I believe there is a sporting feeling of fair play developing in America that is reaching home. We must have adequate laws, adequate government support, and if the thirteen million hunters and fishermen who pay the bill of twelve million dollars a year to carry on conservation—to say nothing of cranks and sentimentalists, men and women who know nothing of the subject about which they speak—if those who pay the bill will get together we shall be on our way to secure good state legislation and good national legislation.


ABSOLUTELY PROHIBITED
SALE PERMITTED FROM CERTAIN WATERS
PERMITTED IF BROUGHT INTO STATE
PROHIBITED APRIL 15 - JUNE 1 (GA)
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THOSE TAKEN IN STATE MAY BE SOLD BETWEEN JULY 1 - MARCH 31
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THE ROLE OF FERTILIZERS IN PONDFISH

O. Lloyd Meehean
U. S. Bureau of Fisheries

Most present day scientific studies in pondfish culture have been influenced by the work of Harvey, Frisch, Naumann, Thienemann, Nordqvist, Pearsall, Krogh, and others who have found correlations between the presence or absence of saltwater fish and phytoplankton, or have been able to classify lakes as to the abundance of fish on the basis of phytoplankton, or who have studied the food of zooplankton and found certain types or species of algae in their stomachs. At the same time the fish culturists, and especially the Germans, culture crustacea, such as *Daphnia magna* or *Moina,* with materials having high protein content, such as ox blood.

The point that will be stressed here is that there are actually two food cycles operating in the pond. One involves the utilization of phytoplankton and the other does not. The former has its place and is important in pondfish production, but the latter has been overlooked almost entirely. The studies made in the south in the last two years have been based upon the latter type of food cycle or at least with it in mind. These cycles run approximately as follows:

1. **Fertilizer**
2. **Ammonia (Formed by bacteria and mycoides)**
3. **Nitrites (Nitrosomonas)**
4. **Nitrates (Nitrobacter)**
5. **Plant protein (Phytoplankton and other plants)**
6. **Zooplankton (Rotifers, Cyclops, ostracods, cladocera)**
7. **Fingerlings**

1. **Fertilizer**
2. **Bacteria (Forming ammonia, etc.)**
3. **Zooplankton (Feeding on bacteria)**
4. **Fingerlings (Using plankton)**

One can readily see that the first cycle involves a long time element. As a matter of fact, although bass are hatched in March and April in Oklahoma and Louisiana, the maximum production of phytoplankton is not reached until the middle of July and first part of August which is long after the fish are capable of utilizing any appreciable amount of plankton food.

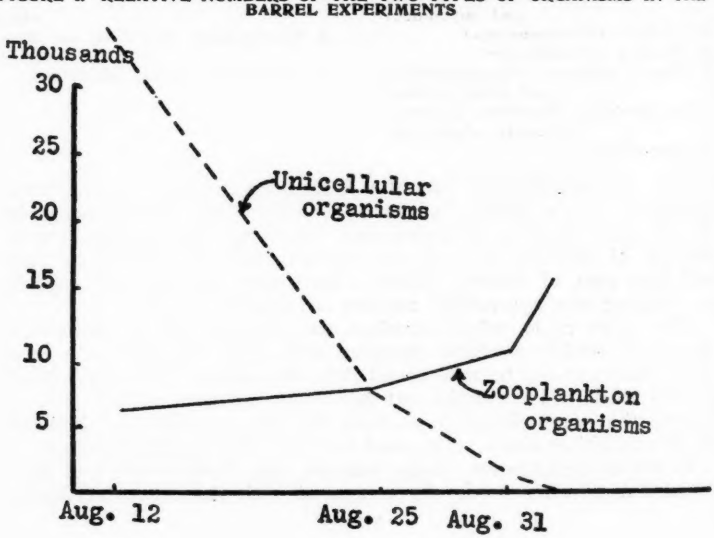
The other cycle, which involves the presence of an immediate supply of readily available proteins, will reach its maximum in a short time and can be maintained thru the season. The importance of this cycle was brought out last year through experiments in barrels that were designed to show the relative value of different fertilizers either alone or in combination with superphosphate.

In these experiments sheep manure, soy bean meal, and cottonseed meal were used. As compared with the other fertilizers,

sheep manure is relatively low in proteins and lacks vitamins entirely. Soy bean meal has about the same protein content as choice cottonseed meal and also has vitamins "A" and "B," but is lacking in potassium and phosphorus. According to experiments at the University of Heidelberg and analyses of the U. S. Department of Agriculture, cottonseed meal contains all the vitamins, and in addition the elements potassium, phosphorus, and magnesium which are all necessary for bodily well-being.

During the course of the experiments, soy bean meal produced from ten to thirty times as many organisms as the same amount of dried sheep manure per given volume of water, depending upon the combination with superphosphate. Cottonseed meal produced from six to seven times as many organisms as soy bean meal. Soy bean meal fostered the growth of phytoplankton organisms such as diatoms, while cottonseed meal did not. This indicated that there was some constituent of soy bean meal that was not readily available to zooplankton organisms, but was being converted into nitrogen compounds and utilized by the phytoplankton. At the beginning of the experiment all of the fertilizers produced large numbers of minute organisms such as rotifers and protozoa. As time went on these decreased in number while the number of crustacea and chironomids increased. A curve drawn for these two classes of organisms showed an inverse ratio as in Figure 1.

FIGURE I. RELATIVE NUMBERS OF THE TWO TYPES OF ORGANISMS IN THE BARREL EXPERIMENTS



This evidence seems to indicate that the crustacea utilize the protein and carbohydrate substances from the fertilizer either directly or thru the bacteria and unicellular organisms.

The outstanding result was the lack of phytoplankton in the cottonseed meal experiments and the disappearance of the unicellular organisms and rotifers as the crustacea and chironomids increased in numbers. It meant that the phytoplankton is not absolutely essential and that the food value of the fertilizer could be utilized in a direct manner somewhat similar to the one outlined. It is upon this idea that the experiments were based during the past summer.

Perhaps a little more explanation is necessary: Bond (1933) showed that *Artemia* grows in a pure culture of algae but that if bacteria are added the death rate is decreased. He also showed that other workers on the food of zooplankton had not given enough consideration to bacteria as food. He found that *Artemia* would grow in a sterilized culture of dead protozoa until the bodies were used up and then growth would stop. This idea of articulate food for zooplankton organisms bears out the observations in the fertilizer experiments.

Most pondfish culturists have seen the increase in abundance of daphnia or other crustacea soon after a pond has been fertilized. *Daphnia magna* will appear in swarms in ponds to which green grass has been added or in ponds on newly flooded pastures. The rate of reproduction of plankton organisms is somewhat in proportion to the amount of organic matter in the water up to the point where the dissolved oxygen becomes the limiting factor. Fish production is dependent upon the rate of reproduction of these organisms so that any increase in organic matter in the pond increases the rate of reproduction of zooplankton and indirectly the size of the fish and the number that can be produced on an acre.

Four ponds were set aside for experimental purposes at Natchitoches. It is the first year of operation for the hatchery so the pond bottoms were bare to begin with. One may assume that about the same conditions existed in all ponds since the whole had been a cotton field before its use as a hatchery. It might be well to state that no forage minnows were used except those that came thru the pump.

It was thought advisable to start all of the ponds with the same amount of fertilizer to begin with and after the zooplankton was well established to decrease the amount of fertilizer per week in two of them. The other two were to be fertilized heavy enough to keep the dissolved oxygen down to almost the limit that the fish could stand. As it turned out the hatch in two of the ponds was a failure due to causes outside the experiment. The other

two were fertilized for different periods during the season. A third pond selected from among those that were to receive ordinary treatment was fertilized lightly with cottonseed meal starting about the time that the fry hatched so that the plankton and consequently the fish had a late start.

A fourth pond was given about one and one-half tons of cow manure from animals fed upon cottonseed meal and hulls. This was added at the beginning of the season. A fifth pond, which might have been any of the remaining ponds at the hatchery and happened to be the best producer of the unfertilized ponds, was used as a check. This pond received about six hundred pounds of manure early in the season. Only the ponds that have been drained will be considered so that actual results are used.

The number of weeks that the various ponds were fertilized and the amount of fertilizer per week for each pond with the production per acre and length of the fish on July 25 are shown in Figure 2. There is an apparent discrepancy in the fertilizer due to the fact that treatment had to be eliminated once or twice due to the low oxygen content of the water. Each pond embraces 0.86 acres and the average depth is from ten inches in Pond 1 to twenty-five inches in Pond 6.

FIGURE 2. SHOWING THE AMOUNT OF FERTILIZER USED IN EACH POND AND THE PERIOD OF TIME INVOLVED

Pond No.	Rate per acre per week	Number of weeks	Total number of pounds used	Production per acre	Size in Inches July 25
1.	41.36	14	498 (meal)	6,395	2 8/16
2.	—	—	3,488 (manure)	2,940	2 3/16
6.	65.77	17	905 (meal)	12,345	3 6/16
8.	66.37	13	685 (meal)	11,090	2 11/16
10.	—	—	600 (manure)	7,757	2 1/16

Ponds 6 and 8 were fertilized heavy enough to keep the dissolved oxygen down to about 3-4 parts per million. The maximum oxygen content, after it had once dropped, was 5.5 p.p.m. and the lowest was 1.2 p.p.m. These two ponds were given about 50-55 pounds of meal per week depending upon what they could stand while Pond 8 received 100 pounds on one occasion.

The first fertilizer was added on March 11. The first school of fry was seen in Pond 8 on March 28 and two more soon after. A school estimated at 2,000 was seen in Pond 6 the first of April so that the hatching period can be considered from March 20 to the second week in April.

On May 24 the average length of the bass in these two ponds were two and one-half and two and seven-sixteenths inches respectively. That is as large as any of the fish in any pond not fertilized with cottonseed meal were on July 25. It represents growth in about two months to a size ordinarily reached in approximately four to six months under ordinary conditions and there were more fish per acre than in any of the other ponds.

At this point the experiments diverged. The fertilizer in Pond 8 was discontinued after June third. Both ponds were seined on June first to remove an excess number of fish which appeared to cause crowded conditions. Approximately 3,000 were taken from Pond 6 and 2,000 from Pond 8.

When the fish were measured on June 29 those in Pond 6 had grown five-sixteenths of an inch while those in Pond 8 had not grown at all. There may have been an error in sampling in the latter pond either in May or June for it seems that there should have been some growth between the two sampling periods. The fertilizer was discontinued in Pond 6 after July third, and the measurements were three and six-sixteenths inches for those from Pond 6 and two and eleven-sixteenths inches in Pond 8 on July 25.

These ponds were drained in August and yielded approximately 7,600 fingerlings apiece. The production per acre was 12,345 for Pond 6 and 11,090 from Pond 8. There was apparently no growth from July 25 to the time the ponds were drained late in August.

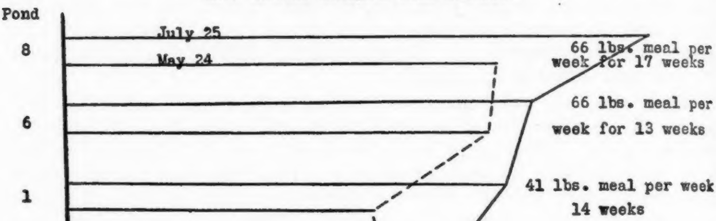
Pond 2 was given one and one-half tons of manure from cows that had been fed on cottonseed meal and hulls. This was put in the pond a couple of weeks before the fry, or about the middle of April. It produced an abundance of crustacea and the fry got off to a good start. In Pond 1 the fry began to hatch about April 10 and fertilization was started on April 1, using about 36 pounds per week.

The fish in Ponds 1 and 2 measured one and twelve-sixteenths and one and fourteen-sixteenths inches respectively on May 24. Those in Pond 1 continued to grow at an increasingly rapid rate until July 25 when they measured two and one-half inches, while those in Pond 2 almost stopped growing between June 29 and July 25 and measured two and three-sixteenths inches at that time.

This is further proof of Dr. Wiebe's belief that it is better to fertilize in small quantities over the season than to add all the fertilizer at one time. Pond 1 was drained on September first and yielded 6,395 fish per acre which is not a large crop but it is remarkable in that the water level could not be maintained and the average depth was ten inches less all season. Pond 2 yielded only 2,940 fish per acre under more ideal conditions since there was no brood stock in the pond during the summer.

Pond 10 was fertilized with 600 pounds of manure about the last of March. The fish were one inch long on May 9 and grew to two and one-sixteenth inches by July 25. The yield was 7,757 fish when the pond was drained on September 9. For some unaccountable reason this pond produced better than any of the ponds except those in which cottonseed meal was used. The following liagram represents the size of the fish in the ponds on various dates.

FIGURE 3. THE AVERAGE MEASURED LENGTH OF FISH IN PONDS AT DIFFERENT DATES DURING THE SEASON



SUMMARY

From such data as has been available, it has been determined that bass can be grown to a size large enough for stocking without the aid of forage minnows and that the size of the fish in heavily fertilized ponds is more uniform than in ponds where less food is available. It has also been determined that these fish will attain an adequate size for stocking at a much earlier date than heretofore has seemed possible. From present observations it seems that growth is somewhat in proportion to the amount of fertilizer used and that it is necessary to continue the use of it through the season.

These experiments must be considered as exploratory since, at the beginning of the season, almost nothing was known about cottonseed meal as a fertilizer for fish ponds or how it would act under actual fish cultural conditions. Although these experiments have been handicapped by mechanical conditions at the hatchery, they are significant in that they show the possibilities of cottonseed meal as a fertilizer and the advisability of fertilizing ponds much more heavily than has previously been attempted. They are significant because, if the growing season can be shortened, there will be a saving in overhead, pond space can be better utilized by doing double duty each season, and larger fish can be produced and maturity attained quicker.

Experiments will be continued to find the amount of "carry-over" from one season to the next due to the formation of unavailable compounds from the fertilizer such as ligno-proteinates formed with the minerals of the water. It will be necessary to determine if smaller amounts of fertilizer are needed after the first season as seems at pres-

ent to be the case. Experiments will be conducted with other high protein content materials to determine their value as fertilizers. Likewise there is much to be done with various minerals and vitamins to determine what part they play in fish production and growth. Forage food such as freshwater shrimp and minnows will be used in conjunction with cottonseed meal during the coming season. At present there is an indication that the utility of fertilizers decreases as the size of the fish increases and with their added need for larger food.

It was felt that actual figures as to size and number of fish would be better appreciated, therefore the scientific data from the chemical or biological standpoint has not been emphasized. In conclusion one should stress the fact that it is no longer a question of putting a specified amount of fertilizer into the water and hoping for the best. It is a question of what fertilizers contain the largest amount of readily available food for organisms that support bass, and how much is necessary to produce a maximum amount of food in the shortest possible time.

Bibliography

Bond, Richard M.
1933. A contribution to the study of the native food cycle in aquatic environments. Bull. Bing. Ocean. Coll., Peabody Mus. Nat. Hist., Vol. 5., pp. 1-89

Harvey, H. V.
1928. Biological chemistry and physics of sea water. Macmillan.

Lundbeck, Johannes
1926. Ergebnisse der quantitativen Untersuchungen der Bodentierwelt norddeutscher Seen. Zeitschrift für Fischerei, Band 24.

Shelford, V. E.
Ecological Succession. III. A reconnaisance of its causes in ponds with particular reference to fish. Biol. Bull., Vol. 21.

Wacksmann, Salman, and E. R. N. Lyer
1932. Synthesis of a humous nucleus, an important constituent of soils, peats and composts. Journ. Wash. Acad. Sci., Vol. 22.

Walter, Emil
1927. Dunungsversuche in den Teichen den Bayerischen Landsfischereivereins der Bernaid. Allg. Fischereizeitung, Band 42, pp. 114-115.

EXPERIMENTS WITH COMMERCIAL FERTILIZERS IN REARING LARGEMOUTH BLACK BASS FINGERLINGS

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This report covers the entire area devoted to rearing fingerling largemouth black bass during the 1932 season and includes four ponds, of the 1933 season, that have been drawn and the fish shipped.

A total of 35 pounds with a combined area of 70.6 acres were used to rear bass to the fingerling stage in 1932. Twenty-one of these ponds had been used as spawning ponds during the spring and after the adult fish had been removed, were stocked with small bass for the remainder of the summer. The other 14 ponds were used as rearing ponds during the entire season. All are dirt ponds supplied with water from a well. The rain that fell was held and during the summer only water sufficient to take care of the seepage and evaporation was added.

In an effort to increase the production of fingerling bass, forage minnows, commercial fertilizer and cottonseed meal were used in some of the ponds during the summer. It is our intention to give the methods followed, the results, and where possible, corrective measures that have been advanced for the ailments that were encountered. This is the first season that commercial fertilizer and cottonseed meal have been placed in the ponds and we are indebted to Dr. Davis of the Bureau of Fisheries for helpful suggestions and information on the work.

There is a wide difference in the fertility of the hatchery ponds. Some have a natural top-soil bottom with an average growth of aquatic vegetation while others have a clay hard-pan bottom and are so infertile that attempts to transplant vegetation in them have failed. All these conditions make a variation in the output of the ponds and also regulate the amount of fertilizer that can be used.

Only forage minnows and fertilizers were resorted to for creating a food supply for the fish. Examination of the stomach contents of the bass shows that some of the fingerling fish ate the cottonseed meal when it was applied to the surface of the water. In the past, attempts to feed young bass on ground fish have for some reason failed. Only a few individuals have taken the ground food and a rapid growth has made their presence in the pond a menace.

In this paper three separate classifications of the rearing ponds are made. Table 1 contains ponds in which bass fingerlings were placed without either fertilizer or forage minnows; Table 2, ponds in which bass fingerlings were placed with fertilizer but without

forage minnows; and Table 3, ponds in which bass fry were placed with both forage minnows and fertilizer.

The ponds in Table 1 were used as spawning ponds. After the spawning season the adult fish were removed and the ponds were stocked during June with fingerling bass. As mentioned neither fertilizer nor forage minnows were placed in these ponds. We considered the natural fertility of this lot of ponds superior to that of the ponds in Table 2.

TABLE 1

Pond	Area	Stocked	Shipped
2	.85A	4,000 No. 1¼ Fgls.	2,285 No. 3¼ Fgls.
3	.85A	4,000 No. 1¼ Fgls.	3,320 No. 3 Fgls.
4	.85A	4,000 No. 1½ Fgls.	3,920 No. 3¼ Fgls.
5	.85A	4,000 No. 1¼ Fgls.	2,790 No. 3 Fgls.
6	.85A	4,000 No. 1¼ Fgls.	3,400 No. 3 Fgls.
7	.85A	5,000 No. 1¼ Fgls.	4,450 No. 2¾ Fgls.
8	.45A	3,500 No. 1¼ Fgls.	3,550 No. 3 Fgls.
9	.85A	3,500 No. 1½ Fgls.	3,100 No. 4 Fgls.
10	.85A	4,000 No. 1¼ Fgls.	3,700 No. 3½ Fgls.
11	.85A	4,000 No. 1¼ Fgls.	4,125 No. 4½ Fgls.
12	.85A	4,000 No. 1¼ Fgls.	3,575 No. 3 Fgls.
13	.85A	4,000 No. 1¼ Fgls.	3,200 No. 2¾ Fgls.
14	.85A	4,000 No. 1¼ Fgls.	3,450 No. 3 Fgls.
15	.85A	4,000 No. 1¼ Fgls.	3,700 No. 3 Fgls.

These fourteen ponds with a combined area of 11.5 acres, stocked with approximately 56,000 fingerling bass produced, when the ponds were drawn in September, 48,565 fish averaging about 3⅛ inches long. At the time the fingerling fish were placed in the ponds it was impossible to take the time required to count all the fish. The number of fish stocked in ponds 3 and 12 is by actual count. The survival in these ponds is about 86%. The remainder of the ponds were stocked by estimating the fish with hand nets. The number shipped is the actual count of the fish recovered when the ponds were drawn.

The low output of ponds 2 and 5 is the result of not sorting the fingerlings close enough as to size when the ponds were stocked in June. The weather was very hot and it was difficult to handle the small fish without a loss and they were placed in these two ponds without being sorted as close as they should have been.

The large fish produced by ponds 9 and 11 is the result of an unusual fertilization. During the early summer of 1931 a large area of these two ponds was covered with a rank growth of cattails, which were cut off under the water and killed. The roots decayed and this condition produced an abundance of daphnia and tubificid worms.

The output of the ponds in Table 1 would indicate that without forage minnows or fertilization of the ponds around four thousand No. 3 fingerling bass is the average production that can be expected on .85 of an acre.

The ponds in Table 2, excepting pond 42, were also used as spawning ponds. After the spawning season the adult fish were removed and the ponds were stocked, during the latter part of June, with fingerling bass. These ponds were fertilized but no forage minnows were placed in them.

TABLE 2

Pond	Area	Stocked	Shipped
17	.85A	4,000 No. 1¼ Fgls.	3,900 No. 3¼ Fgls.
18	.85A	4,000 No. 2 Fgls.	3,500 No. 4 Fgls.
19	.85A	4,000 No. 1½ Fgls.	4,020 No. 4 Fgls.
20	.85A	2,500 No. 2¼ Fgls.	2,375 No. 4¼ Fgls.
21	.85A	3,000 No. 1½ Fgls.	3,000 No. 4 Fgls.
22	.85A	2,500 No. 2½ Fgls.	2,325 No. 4 Fgls.
23	.85A	4,000 No. 1½ Fgls.	3,440 No. 3⅝ Fgls.
42	.85A	3,000 No. 2 Fgls.	2,880 No. 3⅝ Fgls.

These eight ponds with a combined area of 6.8 acres, stocked with 27,000 fingerling bass produced, when the ponds were drawn in late September, 25,440 fingerling fish averaging about 3¾ inches long. The number of fish stocked in ponds 18, 20, 22 and 23 is by actual count. The survival in these ponds is about 89%. The remainder of the ponds were stocked by estimating the fish with hand nets. The number of fingerling fish stocked in Table 2 should be increased considerably over the amounts used this season.

This set of ponds was fertilized every two weeks from June 27, to August 22, with 25 pounds of commercial fertilizer and 50 pounds of cottonseed meal to the pond. Ponds 17, 22, 23 and 42 were each fertilized with 125 pounds of 6% nitrogen, 8% phosphorus, 6% potash and 250 pounds of cottonseed meal for the season. Ponds 18, 19, 20 and 21 were each fertilized with 125 pounds of 18% superphosphate and 250 pounds of cottonseed meal for the season.

The cost of the fertilizers used throughout the season was as follows: 6-8-6 @ $1.32 cwt., 18% Superphosphate @ $.92 cwt., and cottonseed meal at $.65 per hundred weight. The cottonseed meal was prime grade with a guaranteed analysis of protein 41.00%, ammonia 7.98%, and nitrogen 6.56%.

It is our opinion that the four ponds fertilized with superphosphate in Table 2 were superior to the ponds fertilized with 6-8-6. It is also indicated that probably under similar conditions at least five or six thousand No. 3 bass can be produced in one of these ponds with fertilizer and without forage minnows.

The ponds in Table 3 were used throughout the season as rearing ponds. All were stocked with bass fry about one-half inch long the last days of April, the number being estimated. Both forage minnows and fertilizers were used. The fish seined out during June were used to stock a part of the ponds in Tables 1 and 2.

TABLE 3

Pond	Area	Stocked	Seined From Pond in June	Shipped
27	1.8A	25,000 Fry	2,000 No. 1½ Fgls.	15,040 No. 3½ Fgls.
28	1.8A	24,000 Fry	NONE	3,585 No. 5 Fgls.
29	1.8A	25,000 Fry	2,000 No. 1½ Fgls.	9,330 No. 3¼ Fgls.
30	1.8A	25,000 Fry	2,000 No. 1½ Fgls.	8,100 No. 3½ Fgls.
31	1.8A	25,000 Fry	2,000 No. 1½ Fgls.	8,075 No. 3½ Fgls.
33	5.0A	50,000 Fry	2,500 No. 2¼ Fgls.	15,470 No. 4¼ Fgls.
34	5.0A	50,000 Fry	3,000 No. 1½ Fgls.	18,280 No. 3¾ Fgls.
35	4.5A	60,000 Fry	NONE	36,170 No. 4 Fgls.
36	4.5A	60,000 Fry	2,500 No. 2½ Fgls.	17,340 No. 3¾ Fgls.
38	7.0A	100,000 Fry	2,000 No. 1½ Fgls.	52,545 No. 3 Fgls.
39	7.0A	100,000 Fry	2,000 No. 2 Fgls.	57,440 No. 3½ Fgls.
40	5.15A	50,000 Fry	3,000 No. 1½ Fgls.	9,525 No. 3½ Fgls.
41	5.15A	50,000 Fry	3,000 No. 2 Fgls.	11,790 No. 3¾ Fgls.

These 13 ponds with a combined area of 52.3 acres, stocked with 644,000 fry, after having approximately 26,000 fingerlings removed during the last few days of June, produced 262,690 fingerling bass when the ponds were drawn in October and November. Assuming that the 26,000 fingerlings removed from these ponds represent about 50,000 fry when the ponds were stocked and deducting that amount from the initial stock of 644,000 fry, we have a survival when the ponds were drawn of about 44%. It is obvious that the optimum number of fry to stock per acre is between fifteen and twenty-five thousand owing to the fertility of the ponds.

In addition to the 336,695 fingerling bass shipped this fall we have saved 800 select bass weighing between ten and sixteen ounces. These fish are being held at the hatchery in a twelve acre pond for a broodstock. Their number was not included in the output of the various ponds. Each season the select fingerling fish are kept to be raised to the adult stage in an attempt to develop a strain of bass that will make a quick growth and mature at one year.

Table 3-A gives the amount of fertilizer and the number of forage minnows placed in the ponds listed in Table 3.

TABLE 3-A

Pond	Fertilizer for Season		Forage Minnows
27	267 lbs. 6- 8-6	533 lbs. cottonseed meal	800
28	267 lbs. 6- 8-6	533 lbs. cottonseed meal	800
29	267 lbs. 6- 8-6	533 lbs. cottonseed meal	800
30	267 lbs. 6- 8-6	533 lbs. cottonseed meal	800
31	267 lbs. 0-18-0	533 lbs. cottonseed meal	800
33	800 lbs. 6- 8-6	1,600 lbs. cottonseed meal	2,500 (medium)
34	800 lbs. 6- 8-6	1,600 lbs. cottonseed meal	2,000
35	800 lbs. 0-18-0	1,600 lbs. cottonseed meal	2,000 (large)
36		2,400 lbs. cottonseed meal	2,000
38		3,200 lbs. cottonseed meal	2,500
39	1,067 lbs. 0-18-0	2,133 lbs. cottonseed meal	2,500
40	800 lbs. 6- 8-6	1,600 lbs. cottonseed meal	1,350
41	800 lbs. 6- 8-6	1.600 lbs. cottonseed meal	1,350

The ponds in Table 3 were fertilized every two weeks from May 16, to August 22. Two men in a boat scattered the fertilizer

around the edges and in the shallow portions of the ponds. All of the fertilizers used showed beneficial results. The best results were obtained with a mixture of superphosphate and cottonseed meal. We do not know whether this combination will yield the best results year after year for it is possible that the continued use of superphosphate will throw the elements in the ponds out of balance and to make the fertilization more complete, nitrogen and potash will have to be added along with the superphosphate. It is probable that better results would have been received from the fertilization if it had been begun earlier in the season.

The golden shiner was used as a forage minnow. They were placed in the ponds on February 12. No small minnows were recovered when the ponds were drawn. Further experiments with a greater number of forage fish per acre seem advisable and might give better results. As they were used in these experiments there seems to be little advantage in the forage minnows.

The production of ponds 27, 35, 38 and 39 deserves separate mention. The fry placed in these ponds was no doubt underestimated and it is probable that the other ponds in Table 3 would have produced a greater number of fingerlings if more fry had been placed in them. Numerous instances of spinal deformities in the fish from pond 39 were noticed. This may have been caused by injury when the fry were transferred from the spawning ponds or it might have been caused by a very heavy infestation with the larval stages of a species of tape-worm.

On August 25, we suffered a loss of about 1,500 fish in ponds 27, 38 and 39. We are inclined to think that the fish probably died from a combination of unfavorable circumstances. Any one of them might under certain conditions have killed the fish but the mortality was probably due to fish weakened by parasites, eating a gorge of cottonseed meal and being exposed to water low in dissolved oxygen. In the future to prevent such losses of fish it might be advisable to apply smaller amounts of fertilizer every week instead of every two weeks and if possible to make analysis of the water in doubtful ponds as the work progresses. Water samples taken for analysis to determine the oxygen content, should be obtained about sunrise on the day that the ponds are to be fertilized. Our experience has proven that the shortage of oxygen is most acute early in the morning.

The amount of fertilizer that can be applied during a season to any given pond will depend upon the fertility of the pond bottom, the presence or absence of vegetation, the amount of seepage, the temperature and the fluctuation of the temperature. With regards to the fluctuation of the temperature, it is our opinion that, while the ponds are being fertilized, after a period of several weeks of extreme high temperatures followed by a cold rain and wind that the drop in the temperature will cause a circulation in

the ponds bringing about a thorough mixing of the water and result in a shortage of oxygen.

Taking into consideration the fact that in applying the fertilizer every two weeks it was probable that the amount of fertilizer applied at one time, under certain conditions, was sufficient to lower the oxygen content so that it was too depleted for fishlife and giving consideration also to the fact that some of the fish in the crowded ponds ate the meal when it was applied: we decided that it would be profitable to try applying the fertilizer every week. This, we thought, would avoid the lowering of the oxygen content and would also give the fish an opportunity to consume more of the meal, if they desired to do so. Therefore, during the 1933 season we increased the stocking intensity of the fry, started fertilizing earlier in the season, applied the fertilizer every week instead of every two weeks and have used less fertilizer owing to the hang-over from last year.

The results of these changes are evident in the output of the following four ponds that have just been drawn.

Pond No. 27, 1.8 acres, stocked with 900 select adult golden shiner minnows and 40,000 bass fry, fertilized with 400 pounds of cottonseed meal and 200 pounds of 18% superphosphate for the season; produced when drawn September 4, 23,985 No. 3 fingerlings and 47 select fingerlings or a total of 24,032 fish. This is at the rate of 13,350 fish per acre with a survival of 60%.

Pond No. 28, 1.8 acres, stocked with 40,000 bass fry, no forage minnows, fertilized with 400 pounds of cottonseed meal and 200 pounds of 18% superphosphate for the season; produced, when drawn September 7, 19,535 No. 3 fingerlings and 582 select fingerlings or a total of 20,117 fish. This is at the rate of 11,176 fish per acre with a survival of 50%.

Pond No. 29, 1.8 acres, stocked with 40,000 bass fry, no forage minnows, fertilized with 400 pounds of cottonseed meal and 200 pounds of 18% superphosphate for the season; produced when drawn September 9, 21,590 No. 3 fingerlings and 204 select fingerlings or a total of 21,794 fish. This at the rate of 12,100 fish per acre with a survival of 54%.

Pond No. 30, 1.8 acres, stocked with 40,000 bass fry, no forage minnows, fertilized with 333 pounds of cottonseed meal and 166 pounds of 18% superphosphate for the season; produced when drawn September 14, 19,762 No. 2⅞ fingerlings and 83 select fingerlings or a total of 19,845 fish. This is at the rate of 11,025 fish per acre with a survival of 49%.

Discussion

MR. E. LEE LECOMPTE (Maryland): Do you use the cottonseed meal as a fertilizer?

MR. HOGAN: When we started to use it we used it for the purpose of fertilizing the water, but afterwards it was used as food for the fish.

Mr. LeCompte: Your aquatic plant life, then, is being produced by commercial fertilizer instead of from the cottonseed meal?

Mr. Hogan: What was not eaten, of course, furnished fertilizer for the plant life and also, I suppose, for the insect life of the pond. The first year we fertilized every two weeks, but when they started to eat it we decided to put it in every week.

Mr. LeCompte: It really furnishes the food, then, for your fish?

Mr. Hogan: Yes.

Mr. LeCompte: How much do you use to the acre—about one hundred pounds of commercial fertilizer?

Mr. Hogan: No; we started off with the intention of trying to duplicate some of the work of the Bureau, using about five hundred pounds of fertilizer to the acre. Dr. Davis suggested we use two parts of meal to one of commercial fertilizer. We were unable to get that much into the pond the first year; on account of the hangover from the first year we used less this year than we did the first year, because the ponds were richer than they were.

Mr. T. H. Langlois (Ohio): May I ask whether the ponds where you suffered oxygen depletion along about daybreak were clear water ponds with plenty of live aquatic vegetation?

Mr. Hogan: None of our water is clear after we start fertilizing it; most of it is cloudy. Some of our ponds have quite a growth of aquatic vegetation, and some have not. In the ponds that have a growth of vegetation it helps to neutralize the fertilizer. In the ponds where there is very little vegetation we get action quicker than in the ponds where the vegetation is dense.

Mr. Langlois: But in the ponds where you suffered from oxygen deficiency was there dense aquatic vegetation?

Mr Hogan: No, sir.

Mr. Langlois: We have had trouble in that respect in Ohio this year. With us, as with you, the trouble has been just after daybreak. That has occurred in ponds where we had used no fertilizer whatever, clear water ponds with an abundance of vegetation, and the oxygen shortage has come, as I say, early in the morning, just after daybreak, following at least one very dull day. Instead of blaming it on fish fecal matter or other fertilizer we have been inclined to attribute it to the withdrawal of oxygen from the water by the aquatic plants.

Mr. Hogan: Where the water turns green with algae it has the same effect on the water as the vegetation. The ponds I refer to have not as much vegetation as the older ponds have, but it will not be long, if we continue to use the fertilizer, before we shall have a dense growth of vegetation in there, and then we will possibly get the same results that you got.

Mr. G. L. Wickliff (Ohio): May I ask Dr. Wiebe how long the effects of fertilizer are felt in a pond after it is used?

Dr. Wiebe: That is hard to answer. Sometimes it has no effect at all; sometimes you do not get any effect for a week. Sometimes it may last quite a while; sometimes it will last only a very short time. On one occasion I almost had the guts to publish the expression, "physiological moment." You

have to have your organisms ready to benefit by the fertilizer, otherwise you can put in all the fertilizer you like and you wont get any results. I cannot answer definitely; things just do not happen in such a definite manner.

MR. WICKLIFF: It is recommended that fertilizer be used every two or three weeks. If you do that for a period of two months, we will say, there is an accumulation of toxic products in your ponds; but is the result of the first fertilization washed away by the time you fertilize a second time?

DR. WIEBE: It depends on the plant growth and the plankton growth—it depends on a lot of things. I am disinclined to believe that even coarse vegetation or a thick growth of algae will decrease the oxygen appreciably during the night as long as that vegetation or growth of algae is alive. In our ponds at Fairport we get enormous growths of vegetation, but as long as that vegetation is alive we have no trouble with oxygen deficiency. About a year ago I carried out an experiment with reference to the use of oxygen during the night by the algae. I had an aquarium in the museum that was just soup, but that was live algae, and there was no suspended matter—all the dead matter was on the bottom. I took samples from two areas in the aquarium, which was exposed to the air. At the time I took the first samples I filled several bottles with water from that same aquarium, but I could not get into the bottles any of the decaying organic matter that was at the bottom of the water in the aquarium. Every two hours I took a sample from the aquarium, and at the same time also determined the oxygen in the water in the bottles, which were exposed to the sunlight the same as the water in the aquarium. During the night there was a considerable decrease in the amount of oxygen in the aquarium, but in the bottles there was no decrease in oxygen. The point is that the algae do not use an appreciable amount of oxygen as long as they are alive. If they did there should have been a decrease in the oxygen in the bottles. I carried out a similar experiment in a pond outside, with the same results.

MR. WICKLIFF: With the present intensive cultivation of black bass, where you increase the number of fish per acre in a pond, is it possible to get so many fish in the pond that the fish themselves cause the oxygen content to decrease?

DR. WIEBE: Yes, I would say so, especially where you depend on artificial food. If the fish are crowded I think that is possible, although in our pond work we never get that many fish in. I wish that we could.

MR. LANGLOIS: In one of Dr. Wiebe's papers, entitled, I believe, "Diurnal Variations in Oxygen Content of Fish Ponds," he shows that there is a tendency for the oxygen content of the water to diminish along towards morning, and suggests that this may possibly be attributed to the algae. We have certainly encountered that condition very seriously here; the oxygen content has gone down to a critical point and we have suffered loss of fish at that time. We have lost a great many fish within half an hour after daybreak which up to that time had been sound and in good condition. That apparently corresponds with Mr. Hogan's experience. I am wondering

whether Dr. Wiebe has any other explanation for the diminution of oxygen content that occurs during the night so that it is at a minimum in the morning.

Dr. Wiebe: No, except that undoubtedly in that pond you had decomposed organic matter.

Mr. C. F. Culler (Wisconsin): Last year at LaCrosse we produced 27,225 three inch largemouth fingerling bass per acre. This year in the same pond we produced a little over 20,000 per acre. In a one and one-eighth acre pond we produced 16,000 three inch smallmouth fingerlings. These are just experimental ponds, of course.

The President: That was without artificial food?

Mr. Culler: Without artificial food. With regard to what has been said about the overcrowding of fish, I may point out that along the Mississippi River, in the land-locked slews we have taken a million and a quarter out of a pond that was a little less than six acres in extent. So that when it comes to overcrowding, I am somewhat like the Scotchman—I ha'e me doots; at least I have never seen it so far.

Dr. Field: In Europe they are applying chemicals to the land crop before it is used for a fish pond, and they get the food from the biologic action of the microorganisms on the plants. The result there is about one hundred pounds to the acre. They practically use wheat fields for fish ponds which are several hundred acres in extent.

Mr. Hogan: Bearing out what Dr. Wiebe says in regard to the use of fertilizer, when we first started we did not know anything about it, and do not know much yet, but we did find that each pond had to be treated separately. Sometimes it takes three weeks before the fertilizer will have any effect, and sometimes it takes effect the first few days after it is put in.

Mr. Charles O. Hayford (New Jersey): We have had the same experience in Hackettstown with regard to depletion of oxygen in the morning. Usually it happens with us only after we have had an increase in temperature, starting in at say around 65 degrees and continuing to pick up for two or three days; if we did not watch it carefully, the oxygen has been known to go down to less than one part per million. We had the state chemist there and he found that it was due to the varying depths of the ponds. The minute the water starts circulating it upsets the balance in the pond, but by watching it closely now we can tell pretty well by the actions of the fish what the condition is. The oxygen depletion always takes place between six and eight o'clock in the morning.

Mr. Henry C. Markus (New York): With regard to the fish that died in the morning due to lack of oxygen, was the day that followed a cloudy day, and do you think that has a bearing on the matter?

Mr. Langlois: The day that preceded was a cloudy day; in fact such an occurrence has usually been accompanied by rain, and instead of the rain clearing things up it made matters worse. That has happened to us on several occasions this year, and on each occasion it has followed dull weather.

DR. CARL L. HUBBS (Michigan): This depletion of oxygen in ponds is a perfectly ordinary and accepted phenomenon, occurring in the early morning. That is exactly what takes place in polluted waters and not in waters that are full of vegetation. I have encountered it frequently in examining polluted waters; if we take samples during the day and night we may have depletion of oxygen and anaerobic decomposition before morning, so much so that the water will run black with iron sulphide, whereas in the same spot at two o'clock in the afternoon the water will be very highly supersaturated with oxygen. That has occurred in our experience only in waters with a very high organic content—that is, with high pollution. Of course this fertilizing of ponds is just one form of water pollution, if you want to look at it in that way. We have waters that are so full of vegetation of different sorts that you can hardly move through the water, and yet there is no marked depletion of oxygen unless, as Dr. Wiebe says, the plants are dead.

DR. W. J. K. HARKNESS (Ontario): Dr. Ricker, in his investigations in trout streams in Ontario, found that at about four to six o'clock in the morning during the summer there was the smallest supply of oxygen, and I think that is what everyone who has carried on investigations with regard to oxygen supply in the water has always recognized—that in the morning you get the lowest supply, and if there is a large amount of organic matter present in the water you probably get oxygen depletion. At any rate at that time you get a much lower supply than at any other time during the day.

MR. CULLER: One solution of the problem of depletion of oxygen content which has been offered, and which seems thoroughly logical, is this: Ponds may be fertilized to the extent of producing a superabundance of daphnia, which, in turn, have depleted the oxygen content of the water in the night.

THE CALEDONIA SHRIMP *DIKEROGAMMARUS*

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Introduction

The Caledonia shrimp has for a long time been known as a valuable fish food and has often been introduced into trout streams. The two common species, in Eastern North America are *Dikerogammarus fasciatus* and *D. limnaeus,* but there has been a great deal of confusion as to their identity and not much is known about the particular habitat conditions each prefers.

This paper deals with a comparative study of the external morphology and of the habitats of the above mentioned species. The purpose was to test the constancy of the characters generally used to separate the two species. The material came chiefly from Cayuga lake and streams in central New York, and was in part collected by the writer. It is now in the zoological collections of Cornell University. The work was done under the direction of Professor G. C. Embody, to whom the writer wishes to express his thanks.

Taxonomic Status of the Two Species

Gammarus fasciatus was described by Thomas Say in 1818. Sidney I. Smith, in 1871, described *G. lacustris,* and in 1872 redescribed it as *G. limnaeus,* at the same time enlarging on Say's description of *G. fasciatus.* In this detailed account Smith points out many differences between the two species, but many of these specific characters seem to have been considered by later authors unworthy of systematic consideration.

In 1898 the Rev. Thomas R. R. Stebbing split the genus, *Gammarus.* He included *G. fasciatus* in the new genus *Dikerogammarus,* but *G. limnaeus* is not mentioned. In 1906, however, in the *Addenda et Corrigenda* of *Das Tierreich* he says that *G. limnaeus* should remain in the old genus *Gammarus.*

The only difference between the genera, *Dikerogammarus* and *Gammarus* is that the former has spiniferous tubercles on the fourth and fifth abdominal segments, while the latter has fascicles of spines, but no tubercles.

Stebbing probably had no specimens of *G. limnaeus* and was forced to rely on Smith's account. Smith does not mention the tubercles on *G. limnaeus* but does so in the case of *G. fasciatus.* Hence it might be assumed that *G. limnaeus* did not have them.

This difference is small enough at best, and in the specimens examined in the course of this study, *G. limnaeus* was often found to have tubercles fully as large as, or only slightly smaller than those on *D. fasciatus.* According to Stebbing's own key, this would put both

species in his new genus, *Dikerogammarus*. See Figs. 1, 2, 3, and 4.

If we sum up the differences recorded by various authors between these two forms, we see that several of the characters given in the earlier accounts will have to be discarded.

Smith said that *G. fasciatus* had no spines on the posterior margin of the propodus of the first gnathopod of the male. Weckel found such spines present, although smaller than those on *G. limnaeus*.

Smith, Weckel, and others have stated that in *G. fasciatus* the secondary flagellum of the antennule is composed of 5 to 6 segments, and in *G. limnaeus,* 2 to 4. Huntsman, however, finds the number in *G. fasciatus* vary from 3 to 6.

Henry W. Fowler, (1911), says that *G. fasciatus* is usually pale translucent brownish, so the color mentioned by Say can no longer be used in the determination of the species.

Smith states that *G. fasciatus* has a median fascicle of spines on the sixth adominal segment, while *G. limnaeus* does not possess such spines. Weckel, on the other hand, says that *G. limnaeus* may have such spines.

Most of the characters given in the earlier accounts are, as Huntsman says, "differences of degree and not easily applied." Those definite characters which have not been proved unworthy of systematic consideration may be summed up as in Table I.

TABLE I

Characters Found Worthy of Systematic Consideration, According to Authors

D. limnaeus	*D. fasciatus*
Distal segment of outer ramus of third uropod with plumose hairs on the sides.	Distal segment without plumose hairs on the sides.
Telson without lateral hairs.	Telson with lateral hairs.
Fourth and fifth abdominal segments without tubercles.	Fascicles of spines on fourth and fifth abdominal segments raised on distinct tubercles.

Methods of Recording Observations

In determining the species for the purpose of this investigation, the condition of the distal segment of the outer ramus of the third uropod was used, because it seemed to be the most generally accepted character, and the one usually given in keys. Those with plumose hairs on the side and end of the distal segment were called *D. limnaeus*. Those without hairs of any kind on the side of the distal segment and without plumose hairs on the end, were called *D. fasciatus*.

A third group, which for convenience was called Intermediate, consisted of those having plumose hairs on the end only, and a few with straight hairs on the side.

Record of Observations

1. Hairs on the antennae.

Weckel states that the antennae of *D. limnaeus* have fewer hairs than in *D. fasciatus*. This is usually true, but the difference is often very slight. For example, in the *D. fasciatus* from Price Spring Brook, Auburn, N. Y., and the *D. limnaeus* from Newfield, N. Y., there was as much variation within each species as between them.

This character, therefore, does not seem to be constant enough to be of use in separating the two species.

2. Secondary flagellum of first antenna.

In the case of these structures, I have found the variation to be even greater than that recorded by Weckel or Huntsman. *D. fasciatus* was found to have from 3 to 7 segments, as shown in Table II.

TABLE II

Table Showing Numbers of Segments on the Secondary Flagella

No. of segments in secondary flagella	2	3	4	5	6	7
No. of times occurring with D. fasciatus	–	24	55	45	14	1
No. of times occurring with D. limnaeus	10	48	24	12	–	1

It is evident from the above Table that the number of segments in the secondary flagellum is useless in separating the two species.

This character shows a great deal of local variation in each species.

3. First and second pair of gnathopods

The differences between the gnathopods of the two species, both in the male and the female, are very slight, so it is almost impossible to separate the species by means of this character.

4. Hairs of fifth paraeopod.

In the course of this study there at first appeared to be a constant difference in the length of the hairs on the posterior margin of the bases of the fifth paraeopods. They seemed to be always longer on *D. fasciatus*. If the length of the hairs was plainly more than one-half the width of the carpus of the same leg, they were considered long, if less than that, short.

The number of each type found were as follows:

D. fasciatus.

Long hairs—100.

Short hairs—29. (15 of these from one place).

D. limnaeus.

Long hairs—6.

Short hairs—116.

This character, therefore, can not be relied on in the determination of species.

5. Hairs on lateral margins of telson.

According to all accounts examined, *D. fasciatus* has hairs on the lateral margins of the telson, while *D. limnaeus* does not have such hairs.

I have found *D. limnaeus* to have such hairs in about 40 per cent of the specimens, although they usually are smaller and often there is a hair on one side of the telson and not on the other.

6. Color.

I have found the coloration to vary considerably in both species, and local variations are very pronounced. As Fowler says, the coloration of *D. fasciatus* may vary from that described by Say to a "pale translucent brownish," which is typical of *D. limnaeus*, and a few of the *D. limnaeus* examined were found to have brownish spots on the sides of the abdomen.

7. Distal segment of outer ramus of third uropod.

As was said before, this character was the one used to separate the species in the course of this investigation. All the other characters examined have been found to occur in conjunction with both *D. fasciatus* and *D. limnaeus*, types of third uropod.

But this character is variable, and the following types were found.

A. *D. fasciatus.*
   1. Straight hairs on the end of the distal segment, and no hairs on the sides. Figs. 5 and 6.

B. Intermediate Types.
   1. Straight hairs on the end and one or two straight hairs on the side. Fig. 7.
   2. One or more plumose hairs on the end only. The pinnae on these hairs are usually smaller than those on the plumose hairs, having their origin in the basal segment of the same uropod. This is not an uncommon condition and it makes up the bulk of the "Intermediate" type. Fig. 8.
   3. One or more plumose hairs on the end, and a straight hair on the side. Fig. 9.
   4. One or more plumose hairs on the end and one plumose hair on the side very near the end. Only one or two were found which could be put in this group. Fig. 10.

C. *D. limnaeus.*
   1. Plumose hairs on the sides and end of the distal segment. Frequently there is only one plumose hair on one side of the distal segment of only one uropod. Fig. 11.
   Usually there are two or three on each distal segment, but there may be as many as four lateral plumose hairs with a straight hair coming from near the base of one or more of the plumose hairs. Figs. 13 and 14.

The accompanying Table III. shows the frequency of each of the three principle types found.

TABLE III

Frequency of Each Type Found in Each Locality

No.	Locality	D. fasciatus	Intermediate	D. limnaeus
1.	Locality?	15	0	0
2.	Locality?	0	1	6
3.	Locality? 1910	3	2	1
4.	Locality?	12	1	3
5.	South End Cayuga Lake, near bottom	12	1	0
6.	South End Cayuga Lake, in weeds	12	0	0
7.	West Shore Cayuga Lake	12	9	0
8.	Price Spring Brook, Auburn, N. Y., 1928	23	2	0
9.	Price Spring Brook, Auburn, N. Y., 1931	23	1	0
10.	Newfield Stream, near Newfield, N. Y.	0	1	12
11.	Newfield Stream, 1931	0	0	32
12.	Hazzard's Brook, near Ithaca, N. Y.	15	0	0
13.	Rochester, N. Y., 1926	7	0	0
14.	Rudman's Pond, Rochester, N. Y., 1931	12	5	2
15.	N. Y. S. Hatchery, Caledonia, N. Y.	6	0	32
16.	St. Lawrence—Red Mills, 1930	7	4	2
17.	Little Clear Pond, near Saranac, N. Y.	0	0	16
18.	Hackettstown, N. J., 1929	15	1	0
19.	Long Island, 1931	0	19	2
20.	Stump Lake Cut Off Pond, N. Dakota	0	0	9
21.	Metigoshi Lake, N. Dakota	0	0	9
22.	Spring Run—Indian Creek, Utah	0	0	12
		174	47	136

The shape of the distal segment may also vary, and is frequently deformed. (Figs. 6, 7, and 8). It is sometimes anastomosed with the basal segment. (Fig. 16). In these cases the hairs are usually arranged in the usual manner.

Frequently the third uropods on one individual are of different lengths.

These abnormalities prove nothing one way or the other in the determinaton of species, but their frequency seems to illustrate the general lack of uniformity.

8. Relation of each species to the hardness of the water.

It has generally been thought that *D. limnaeus* inhabited waters rich in calcium carbonate, or "hard water" and that *D. fasciatus* inhabited waters with little calcium carbonate. (Titcomb, 1927, and 1930). Pentland, 1930, states that *Gammarus* were not found in those parts of Ontario in which the basic rock formations are granites and gueisses, and the water is for the most part soft and acid. The few records I have do not indicate that *D. limnaeus* requires a greater concentration of lime than *D. fasciatus*. Table III shows clearly that the two species may occur in the same place.

Table IV gives the relative hardness of the water in a few of the localities. It is interesting to note that all the specimens from Little Clear Pond, which has the least amount of calcium carbonate, were *D. limnaeus,* while those from Price Spring Brook, which has the most calcium, were all *D. fasciatus,* except for two Intermediates.

A general rule cannot be made from so few examples, but they prove that *D. fasciatus* may occur in hard water and *D. limnaeus* in relatively soft water.

It is definitely known that Auburn sportsmen introduced amphipods from Caledonia, which are mostly *D. limnaeus,* into Price Spring Brook, but none of this species were found there. Both places have hard water, and there seems to be no reason for the disappearance of the *D. limnaeus.* They may have either been crowded out by the indigenous *D. fasciatus,* or the two species may have crossed. Thirty years ago it was a common practice for the state to plant amphipods from Caledonia in other streams and this may account for the fact that the two species are sometimes found in the same place.

TABLE IV

Relation of Each Species to the Hardness of the Water[1]

Locality	D. fasciatus	Intermediate	D. limnaeus	Methel Orange Alkalinity p.p.m. Calc. Carb.
Price Spring Brook	35	2	0	244.5
Caledonia Hatchery	6	0	32	196.
Cayuga Lake	36	10	0	104.
Newfield Stream	0	1	44	97.
Little Clear Pond	0	0	16	17.

[1]Harold M. Faigenbaum, 1929, and F. E. Wagner, 1927, 1928, and 1930, in Reports of N. Y. S. Conservation Department.

CONCLUSIONS

1. The presence of plumose hairs on the sides of the distal segment of the outer ramus of the third uropod seems to be the most reliable character for distinguishing the two species, but even here there are structural gradations.

2. All the other species characters described by authors for each form have been found to occur in conjunction with the uropod condition exhibited by typical specimens of both *D. fasciatus,* and *D. limnaeus.*

3. Both species are subject to local variations, in color, hairiness of appendages, and the number of segments in the accessory flagellum.

4. Both species may occur in the same place. This may be due to planting of "Caledonia shrimp" by the state.

5. *D. fasciatus* may occur in hard water, and *D. limnaeus* in relatively soft water, and vice versa.

6. Both species have dorsal tubercles on the fourth and fifth abdominal segments, which would place them in Stebbing's genus *Dikerogammarus.*

7. Within New York State at least, it is not always practicable to separate the two species, either by morphological characters or by types of habitats.

EXPLANATION OF FIGURES

Figure 1. Last 3 abdominal segments of *D. fasciatus*, from West Shore of Cayuga Lake. Dorsal and lateral views.

Figure 2. Last 3 abdominal segments of *D. fasciatus*, from Price Spring Brook. This was the predominant type from this locality. Dorsal and lateral views.

Figure 3. Last 3 abdominal segments of *D. limnaeus* from Newfield Stream, N. Y. Dorsal and lateral views.

Figure 4. Last 3 abdominal segments of *D. limnaeus* from Stump Lake Cut Off Pond, N. Dak. Dorsal and lateral views.

Figure 5. Short distal segment of third uropod of *D. fasciatus* (collection No. 1, Table IV).

Figure 6. Long distal segment of *D. fasciatus*.

Figure 7. "Intermediate" type of distal segment, with a straight hair on the side and no plumose hairs on the end. The distal segment of the other uropod was without lateral hairs.

Figure 8. "Intermediate" type of distal segment, with plumose hairs on end only.

Figure 9. "Intermediate" type of distal segment, with a straight hair on the side, and one plumose hair on the end. The pinnae of this hair were visible only with the high power objective of the microscope.

Figure 10. "Intermediate type" of distal segment with a plumose hair on the side, but very near the end.

Figure 11. Distal segment of the third uropod of *D. limnaeus*.

Figure 12. Secondary flagellum of first antenna of same individual as in Figure 11.

Figure 13. Distal segment of third uropod of *D. limnaeus*. This is the most common type, although in this particular specimen the other uropod had no plumose hairs on the lateral margin of the distal segment.

Figure 14. Distal segment of third uropod of *D. limnaeus*. This is a common type.

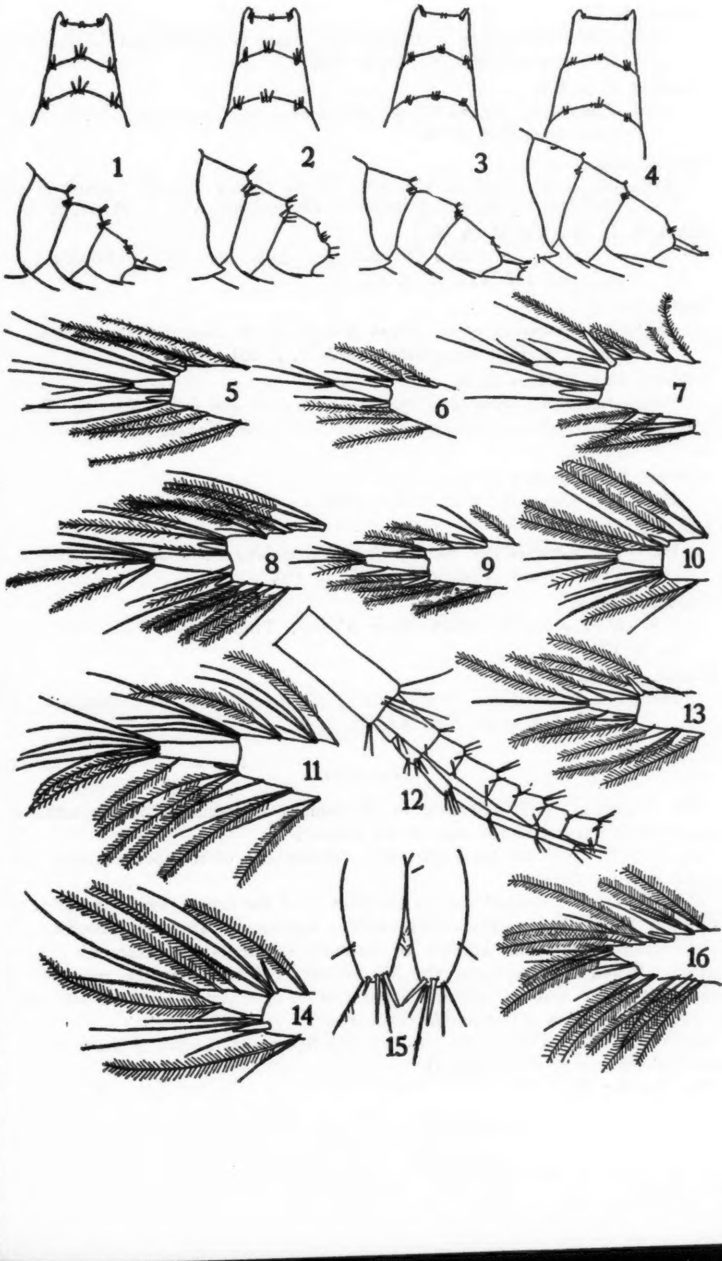
Figure 15. Telson of *D. limnaeus*. From same individual as in Figure 14.

Figure 16. Distal segment anastomosed with basal segment of outer ramus of third uropod. The other uropod on this individual was a normal *D. limnaeus* type.

BIBLIOGRAPHY

Fowler, Henry W.
1911—*Crustacea of New Jersey*. Report of New Jersey State Museum, 1911, p. 193.

Huntsman, A. G.
1915—*Fresh-Water Malacostraca of Ontario*. Contributions to Canadian Biolog. Sessional Paper No. 39b—1915, p. 151.


1
2
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4
5
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7
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15
16

Kunkel, B. W.
1918—*The Arthrostraca of Connecticut.* State Geological and Natural History Survey. Bul. No. 26, p. 105.

Pentland, Ernest S.
1930—*Controlling factors in the distribution of Gammarus.* Trans. Amer. Fish. Soc., 1930, 89-94.

Say, Thomas.
1818—*An Account of the Crustacea of the United States.* Journal of the Academy of Natural Sciences of Philadelphia, Vol. I., Pt. II, p. 374.

Smith, S. I., and Verrill, A. E.
1871—*Notice of Invertebra Dredged from Lake Superior.* Stillman's Journal, Ser. III, Vol. II, p. 453.

Smith, Sidney I.
1872—*The Crustacea of the Fresh Waters of the United States.* Report of the U. S. Fish Commission, 1872-'73, p. 651.

Stebbing, Rev. Thomas R. R.
1898—*Amphipoda from the Copenhagen Museum and Other Sources.* Trans. of the Linnean Society of London, 1896-1900, Second series. Vol. VII, p. 428.

Stebbing, Rev. Thomas R. R.
1906—*Das Tierreich.* Vol. XXI, p. 458.

Titcomb, John W.
1927—*The Fresh-Water Shrimp for Replenishing Food in Trout Streams.* Trans. Amer. Fish. Soc., 1927, p. 150.

Titcomb, John W.
1930—*More about the Fresh-Water Shrimp.* Trans. Amer. Fish. Soc. 1930, pp. 95-100.

Weckel, Ada L.
1907—*The Fresh-Water Amphipoda of North America.* Proceedings U. S. National Museum, Vol. XXXII, p. 40.

Discussion

Mr. Markus: With reference to the number of segments in the antenna, doesn't that vary with the age of the animal?

Dr. Smith: I do not know—it might, but the size of the specimen does not make much difference.

Mr. Markus: I worked out the life history of the isopod, which is not very different from these animals—Mancasellus macruous. Doctors Garman and Richardson studied the number of antenna segments as taxonomic characters. When I worked out the life history, I found that the number of segments in the antenna varied so much with age that I did not see how it could be used as a taxonomic character.

Dr. Wolf (New York): Do you have any figures on the pH of the water in which these species were found?

Dr. Smith: No.

THE BRINE SHRIMP (*ARTEMIA*) AS A SATISFACTORY LIVE FOOD FOR FISHES

ALVIN SEALE
Superintendent of the Steinhart Aquarium

Five years ago there was brought into the Steinhart Aquarium a few small crustaceans slightly less than half an inch in length of distinct reddish color. These animals were constantly active swimming chiefly in an inverted position. They had been secured in the brine ponds near San Mateo, California.

A few were given to our small fish and the results carefully observed. They were taken eagerly and the fish thrived on them so they became an important part of the food used at the aquarium and have continued to be ever since.

During the stormy winter season it was found difficult to secure enough *Artemia* to supply our need and it was to remedy this condition that the writer, in 1930, began a series of experiments and serious research on the brine shrimp. First of all I found there was some question regarding the proper scientific name. The Europeans called it *Artemia salina* and give its distribution as world wide. Others were more inclined to divide them up into several species, the name *Artemia elegans* being given to our western form. However, until more research has been made I prefer to hold with the conservatives and call our animal *Artemia salina*—the brine shrimp.

In visiting the salt ponds where the animals occur in such numbers as to give the water a decidedly red color, I was able to secure quantities of the eggs—small round or cup-shaped bodies, brownish in color and about one-fifth of a millimeter in diameter. These were washed, dried and placed in glass jars. Experiments were then made to determine how long they retained their vitality and under what conditions they could be hatched.

I found the eggs, if properly treated, would retain their vitality almost indefinitely. I am now hatching eggs that were dried in 1930 and get an 85 per cent hatch.

Ordinary sea water is perhaps the most satisfactory medium in which to hatch them. However, they hatch with equal facility in a salt solution made by placing two level teaspoons full of common table or rock salt in one-half pint of water. They will not hatch in fresh water. It is possible therefore for all aquarists—even those living inland—to keep on hand a quantity of these eggs and to have a good supply of live food at any time—winter or summer—within 48 hours by simply hatching out the eggs as directed above.

The young shrimp when first hatched are about one-half millimeter in length and are a splendid food for all young tropicals, in fact in our opinion are superior to *Daphnia* and much cleaner to use as one

runs no risk of introducing *Hydra* and other enemies into the aquarium. Our fish are just as greedy for the newly hatched shrimp as for *Daphnia.*

There is always a tendency with the beginner to use too many eggs at one time. I place ¼ of a teaspoon of the eggs in a three gallon tank of sea water and found I had used too many. The eggs will hatch very well at the ordinary room temperature of 70°. Cold will retard the hatching and warmth will hasten it. In the ordinary temperature of 70° with moderate light the eggs hatch in from 24 to 48 hours and the young may be dipped up with a small net made of bolting cloth and fed at once to the fish. *Do not by mistake pour the salt water in which they must be hatched into your aquarium of fish* or disaster to plants may result.

The shrimp are of separate sexes and undergo about three transformations during life. They reach maturity in about three months and are then slightly less than one-half inch in size. We do not, however, recommend the attempt to grow them to maturity as the sooner they are fed to the fish the better and fresher they are. I have grown them to maturity by feeding with fish flour, which is fish meal ground excessively small, but doubt if they can be grown to maturity in sufficient quantities in captivity to be of commercial value.

I have used these newly hatched brine shrimp with considerable success in feeding grayling and young trout. It would be well for hatching, to keep a supply of these eggs on hand so the newly hatched shrimp may be fed at any time to backward or indisposed young fish I understand that these eggs may now be secured in any quantity from the San Francisco Aquarium Society, Steinhart Aquarium, San Francisco, California.

NOTES ON THE USE OF WATER FLEAS AS FISH FOOD

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Much work has been done by fish culturists within recent years toward developing large scale methods of culturing and feeding daphnia to bass, but little has been written on the subject. Much impetus was given to the use of these organisms (Cladocerans) by the preliminary work of Dr. G. C. Embody in New York State and Mr. C. O. Hayford in New Jersey. (Hayford, 1927).

Davis and Wiebe (1930) and Wiebe (1930) have pointed out that plankton production in ponds can be increased by fertilization of ponds. The object of the work of these investigators was to increase total planktonts of all kinds. In this paper we are concerned with the production of water fleas alone in huge numbers for use as a major food of bass up to a planting size of from three to four inches. It is our object to give here some facts regarding the behavior of daphnids determined from laboratory experiments that may assist fish culturists in growing and maintaining dense cultures, and to point out the various methods of feeding these forms that have been learned from practical experience.

One of the chief advantages of daphnia as a fish food is their ability to attain enormous numbers in a short time. This is due to three factors, viz.; first, the short intervals of time between generations (four to seven days at 70°F for different forms) in these animals; second, large number of young produced by each female; and third, and quite important is the fact that again under optimum conditions each female produces eggs that develop without fertilization, parthenogenitically, into other females so that all animals in a culture pond are the potential producers of other daphnia.

Two other types of individuals frequently occur in cultures, winter egg bearing females and males. Neither of these are wanted in cultures planned for maximum numbers and when present indicate the culture has passed its peak of production and should be refertilized and started anew.

Winter eggs, usually one or two in number, are carried in a special modification of the external covering, the ephippium or saddle, on the back of the female daphnid. These are the sexual eggs of these organisms and will not hatch unless fertilized by the males. Winter eggs give to such individuals as bear them, a characteristic black appearance when they are mature and about ready to be dropped, standing out in clear contrast to the

paler colors of the daphnids bearing them. In the early stages, winter eggs often appear white or yellowish becoming darker gradually as they mature. Once fully developed, the females bearing them die and they break loose from the parent body, float on the surface of water and are often washed in windrows on the windward sides of ponds in enormous numbers. At such times it is possible to gather them literally by the quart for use in hatching and starting new cultures.

Winter eggs require certain stimuli before they will hatch and apparently the most important factor in this regard is freezing. Mr. Henry Marcus of the U. S. Bureau of Fisheries at Rochester, N. Y., who was the first investigator to work out a practical method of hatching winter eggs, has informed us of his experiments with winter eggs and kindly given permission to quote a letter from him.

"Daphnia winter eggs were collected from the bass rearing ponds in Rochester, N. Y., June 28, 1932. One half of the eggs collected were dried and the remaining half were kept in water. Thirty days after the eggs were collected a small portion of both the wet and dried eggs were divided into ten lots and put into water and subjected to freezing temperatures. The freezing process was carried on in the ice cube compartment of an electric refrigerator. At the end of twenty-four hours after the eggs were put into the refrigerator and the water around the eggs had frozen solid one lot of each of the wet and dry eggs was removed and put into a battery jar with a teaspoonful of sheep manure. The remaining nine lots were allowed to thaw out and warm and put back again to freeze for another twenty-four hours. Then another lot each of the wet and the dry eggs were removed and placed in a battery jar. The remaining eight lots were allowed to thaw and warm and then put back to freeze again. This process was continued until the last lot had been frozen and thawed ten times. It was found that after the eggs had frozen and thawed eight times the best hatch was obtained and also the shortest hatching period. The eggs frozen and thawed less than five times failed to hatch. One long continuous freeze will not cause the eggs to hatch. However the number of freezing and thawing periods is decreased as the eggs age and this is especially true of eggs kept in water. I am of the opinion that the freezing and thawing processes serve as a physical process in preparing the egg's shell so that moisture can get to the egg."

Experimenting along similar lines the senior author was able to hatch winter eggs of *D. magna* shipped to California from the Hackettstown Hatchery by Mr. C. O. Hayford last spring. However, in this case the eggs had lain dormant on the dry pond bottom all winter and doubtless had been subject to numerous freez-

ing and thawing periods over the winter. It is evident that distribution of winter eggs of *D. magna* for starting cultures at hatcheries where they are now present offers a much cheaper and easier method than shipment of the living organisms.

There are perhaps three species of Cladocera most suitable for culturing. Each of these forms possesses its own particular advantages. *D. magna* occurs naturally in the North Atlantic States and Canada and is the largest (reaching a length of one-fifth of an inch) most readily handled form. This species does well on either small algae (unicellular) or bacteria and develops nicely in ponds of various sizes where the temperatures do not exceed 75° F. to 80° F. over long periods. A second form, *Daphnia pulex,* is more cosmopolitan in distribution and is similar to *D. magna* in its cultural requirements except that it can perhaps stand somewhat higher temperatures. The individuals of the second species are however, decidedly smaller than those of *D. magna.* Either of these forms does particularly well throughout the spring months and well into June but would require closer watching past this time. The best hot weather forms are those belonging to the genus *Moina,* of which there are three common species. While the fully grown females of this genus are small (about one-twentieth of an inch) the interval between generations is short, two to three days at 75°F. and the food value is high due to the small amount of chitin present. *Moina* will live and thrive in ponds that are excessively rich in food as they are normally found in small exposed barnyard ponds.

In nature, due to the rapidity of reproduction, daphnia soon reach a peak or maximum in numbers as the pond warms up and food in the form of minute algae or bacteria becomes plentiful. This period of maximum numbers does not hold for long and is followed by a protracted period in which but few individuals are present. This period of low numbers, as laboratory experiments have shown, follows the appearance of non-producing males and winter-egg-females. The lack of food and crowding during the period of maximum numbers causes the appearance of these unwanted forms. In culturing daphnia as a continuous and adequate source of food for small fishes, it is necessary to recognize by simple means factors which point toward a decline in numbers.

The signs of incipient or expected decline even when culture ponds or tanks apparently are at maximum numbers are three:

1. The presence of numerous males.
2. The presence of females bearing winter eggs.
3. The absence of young daphnia either swimming free in the water or their absence as embryos in the female's brood chamber.

Regarding the third and most easily observable point, it may be said that a glance at a handful of daphnia dipped from a pond is sufficient for practical purposes. A satisfactory condition of the culture is indicated when the large majority of the animals are females carrying in the brood chambers either newly laid eggs or advanced embryos. (See figure). The newly laid eggs are green in color and easily seen. The advanced embryos give the female a well rounded opaque appearance and when examined with a hand lens the pigmented eyes of the young appear as black spots through the sides of the brood chamber.

If an examination of a culture shows any of the three signs of decline, it is better to feed the remainder of the culture, drain and clean the pond and restart it so that it may be brought to peak of production again as soon as possible. Cultures can be kept going almost indefinitely by the addition of small amounts of fertilizer from time to time in small culture tanks indoors, but for large scale production in outside culture ponds far better results will be had by the former method after any given culture has begun to decline.

The practice of fish culturists of dipping water fleas from ponds by means of fine meshed nets for feeding to fishes materially reduces crowding of the fleas, does not reduce their food supply and is hence a factor of considerable importance in extending the longevity of cultures tending to delay the appearance of males and winter egg bearing females.

Culture Fertilizers

The best fertilizer to use, in the present state of our knowledge, seems dependent upon local conditions and what may work well at one hatchery will fail entirely at another. Some observations have shown that alkalinity of the water may play a major role in the development of dense cultures. It is a well known fact that alkaline waters are, under natural conditions, much more productive of fish foods than acid waters.

The writers have had good success with green cow manure, horse manure, dried sheep manure, and beef hearts (the last in small culture tanks). Dr. G. C. Embody's recommendation of three parts soy bean meal to one part acid phosphate has worked very well in the Friant Bass Ponds near Fresno, California. Hayford (1927) states that he had good success using a combination of twenty quarts of green cow manure, four quarts of menhaden meal, and four quarts of bean meal in concrete ponds thirty feet long, three feet wide and two feet deep. As noted below Hayford has also had excellent success using trout excrement alone in former trout ponds without the addition of other fertilizers. Smith (1932) notes using salt water mussels, cow

manure, and herring meal. Langlois (1931) notes considerable success using sheep manure and superphosphate as recommended by Dr. Embody. Mr. Marcus writes that he has had good results using cow manure and municipal sewage plant wastes. Suffice to say here that the best media for any given location is entirely dependent upon local conditions such as character of water and cheapness and availability of fertilizing materials.

Methods of Feeding Daphnia

As now practiced by fish culturists three methods of feeding these organisms to bass have been developed, viz:

1. By rearing them in the same pond with the bass
2. By rearing them in separate culture ponds and flowing them into the rearing ponds by gravity
3. Feeding by hand from separate culture ponds not connected to rearing ponds.

As noted by Hayford (1932) and McGavock (1932) the first method has proved particularly successful in former trout ponds having rich, silty bottoms containing much decomposing organic matter. One of the main difficulties in this method is that while a dense culture of water fleas may be available at the time the bass fry are placed in the pond, the cultures often run down slowly as the fleas diminish in numbers and winter eggs are cast. When water fleas are cultured in the same pond with the bass it is important to allow only enough water to enter the pond to take care of that lost by seepage and evaporation. Water flowing out of rearing ponds in which daphnia are being cultured carries with it and wastes multitudes of potential food organisms. Further as McGavock (1932) and Smith (1932) state, care must be exercised in fertilizing rearing ponds to avoid too rapid decomposition with consequent oxygen depletion.

In connection with this method of culturing daphnia in the same pond with the bass, several observations made on Pond No. 12, at Hackettstown, in 1931, may prove of interest. This pond had been used for eight years as a wintering pond for trout with consequent deposition of a deep layer of silt and excrement over the entire bottom from six inches to three feet in depth. Hayford (1932) has already presented the gross results obtained from this pond in 1931 showing that 17,157 bass fingerlings three to four inches long were obtained from a plant of 20,000 advanced fry giving a loss of 14.2% and a cost of $6.61 per thousand.

Several additional interesting facts were brought out from our studies of this pond. Plankton hauls taken twice a week while the bass were in the pond showed but slight diminution in quantity of water fleas over the entire period of thirty-eight days the bass were in the pond. In other words, Daphnia reproduction counter-

balanced bass consumption. This in turn eliminated competition for food preventing cannibalism with consequent destruction of many of the smaller sized fish.

It is interesting to note that the maximum variation between the largest and smallest specimens taken from the pond, was only three quarters of an inch. This is a safe variation in so far as cannibalism is concerned as our data on this feature of the work shows that cannibals average more than twice the length of their victims. Variations as high as four and one-half inches between the largest and smallest specimens were obtained from ponds where food was scarce and cannibalism naturally resulted.

It was found that the average length of largemouth bass that had eaten other young bass was three and one-half inches and ranged from an inch and a quarter to five and one-half inches. Smallmouth cannibals averaged three and three quarters inches in length. The average length of the victims of both small and largemouth bass was one and five-eighths inches.

It should be pointed out that using former trout ponds as rearing ponds for bass involves the production of other foods than merely water fleas alone. In the soft silt and excrement composing the rich bottom materials of former trout ponds, "bloodworms," *Chironomus tentans,* and water sow-bugs, *Asellus,* become exceedingly abundant. These the bass fingerlings eat in considerable numbers as they become larger, water fleas being taken at the same time but not in as large quantities as when they are small.

In Pond No. 12, the four dominant foods consumed by largemouth bass in 1931 occurred in the following percentages by bulk:

Water fleas	**49.6%**	**Sowbugs**	**10.3%**
Midge larvae	**38.8%**	**Copepods**	**1.3%**

Thus it is clear that water fleas alone on the average over the entire thirty-eight days the fish were in this pond, furnished about 50% by bulk of total foods eaten. A few scattered miscellaneous forms were also eaten but here the four dominant foods have been recalculated and placed on a 100% basis. These figures are based on the examination of twenty stomachs taken four at a time at intervals until the pond was drained.

Rearing water fleas in culture ponds above the rearing ponds for gravity feed to the latter, is a much more expensive method of construction requiring generally one to four separate culture ponds. However, the organisms can be flowed ahead into the rearing pond as needed. Where more than one culture pond is available, they can be set up and inoculated in rotation so that as soon as one reaches peak of production it may be flowed ahead into the rearing pond and a new culture immediately started again. By this system a continuous supply of food is assured.

One distinct advantage of separate culture ponds is that they offer better chances for observation and control so that the pond may be drained and reset when the culture shows the first signs of decline. A further advantage is the fact that all potential food organisms in a given culture may be utilized. Mosquito larvae and pupae usually live close to the surface of cultures, water fleas swarm through the middle areas, while in the bottom many "bloodworms" and other bottom organisms dwell. In flowing the contents ahead, all these organisms can be fed into the rearing pond so that none are wasted. The rich organic matter and detritus from the culture pond will also assist in building up richer bottoms in the rearing ponds so fed. However the same objection applies to this method that applies to hand feeding,—that it is difficult to get an even distribution of the food animals in the rearing pond particularly if they are of large size, the bulk being eaten near the point of entrance. It seems probable that this method will work best by using small rearing ponds below the culture ponds.

The third method of dipping water fleas from culture ponds entirely separate from the rearing ponds by means of nets, placing them in cans, and dumping them into the rearing ponds as needed, is rather widely practiced at several bass hatcheries. At the Hackettstown Hatchery in the sumer of 1931 the senior author made plancton examinations twice a week of each rearing pond in which daphnia were being fed by hand. Those showing a scarcity of individuals were restocked at once using anywhere from five to fifteen five gallon milk cans of concentrated water fleas from the culture ponds. Stomach examinations made several hours after stocking showed that the bass ate huge quantities of these (often over 2,000 in a single stomach) at once, so that a day later the plancton would again be low. Further, unless the daphnia be well distributed, only a portion of the bass in any given pond can get them before they are cleaned up. At best, it seems that this method, unless carried on in relatively small, narrow ponds where an even distribution of the fleas may be had, offers but a temporary food supply of not too adequate nature. Bass in ponds in which this method of feeding was practiced showed considerable evidences of cannibalism upon draining. However this system has all the advantages in allowing for observation and control but lacks the ease of gravity feeding and has, of course, the added expense of labor for hand feeding.

Lack of data prevents a true evaluation of each method at this time though it has been shown that culture daphnia in the same pond with the bass from trout excrement is an economical and feasible method of feeding bass on a large scale.

The phases of bass culture are in serious need of a thorough quantitative biological study to determine first, the best method of

culturing water fleas on a large scale, and second, to find the most economical and efficient method of getting them to the young bass.

BIBLIOGRAPHY

Davis, H. S., and A. H. Wiebe. Experiments in the culture of black bass and other pond fish. Appendix IX, Rept. U. S. Comm. Fish., 1930 (U. S. Bur. Fish. Doc. 1085), pp. 177-203, 1930.

Hayford, C. O. Artificial production of food for young bass. Trans. Amer. Fish. Soc., 1927, pp. 143-144, Vol. 57.

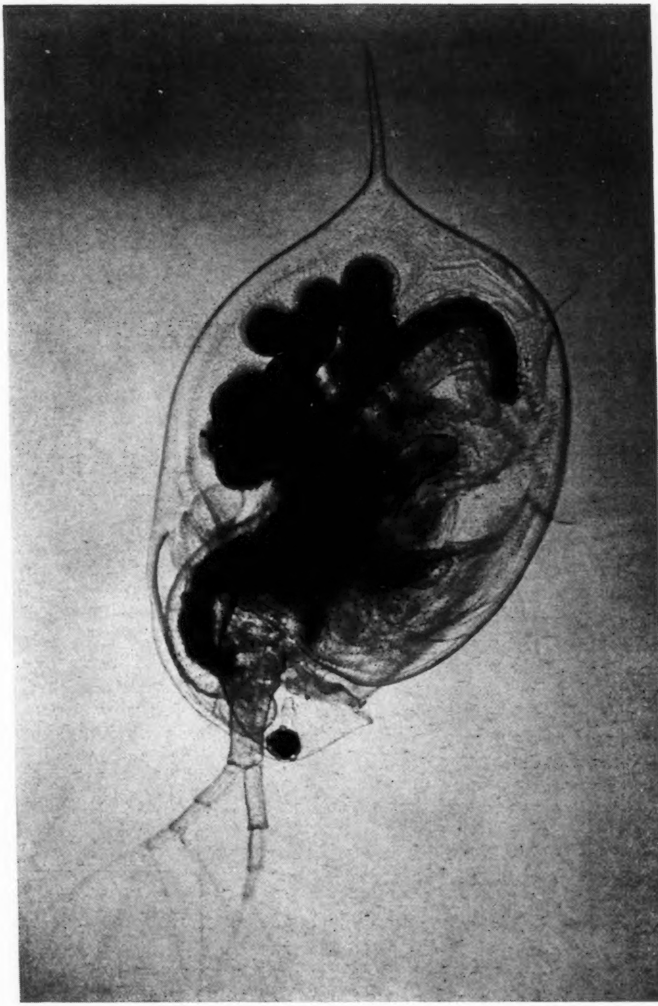
Hayford, C. O. Economic bass culture in trout wintering ponds at the Hackettstown State Fish Hatchery. Trans. Amer. Fish. Soc., 1932, pp. 167-168, Vol. 62.

Langlois, T. H. The problems of efficient management of hatcheries used for the production of pond fishes. Trans. Amer. Fish. Soc., 1931, pp. 106-113, Vol. 61.

McGavock, A. M. Notes on three methods of bass culture. Trans. Amer. Fish. Soc., 1932, pp. 168-170, Vol. 62.

Smith, M. W. The fertilization of water in experimental ponds. Trans. Amer. Fish. Soc., 1932, pp. 317-322, Vol. 62.

Wiebe, A. H. Investigations on plankton production in fish ponds. Bull. U. S. Bur. Fish. 46: 137-176 (U. S. Bur. Fish. Doc. No. 1082), 1930.



Water flea, *Daphnia pulex,* showing summer eggs in the brood chamber. Mag. 18 diameters.

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OBSERVATIONS ON CIRCULAR POOL MANAGEMENT

Eugene W. Surber,
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The outlets of the circular pools at the Leetown (W. Va.) Station are in the centers of the pools. The outlet pipe eighteen inches in height, is threaded at the bottom and screws into a sleeve or elbow set in a circular block of concrete. The circulation in the pool is rotary or centrifugal, and the excrement and wastes from feeding the fish are carried to a zone of relatively still water around the bottom of the outlet pipe.

During the fall and winter of 1932-33, a number of types of outlet screens were experimented with, but none were developed which did not require the pulling of the outlet pipe for cleaning and the use of a brush, or a siphon. However, on an occasion when a screen in a pool containing large fish was removed, it was noted that, with the aid of the activity of the fish, waste materials were pulled out of the pool by suction from the top of the pipe. It was thought at first that with fairly large fish and a two inch outlet pipe the pool could be had self-cleaning without any device about the pipe, but traps set at the mouth of the drain soon showed that the large fish would leave the pool readily over the shallow edge of the center outlet pipe. At this point, Mr. J. H. Crowl, of Shepherdstown, W. Va., who had been doing nearly all of our plumbing work and is skilled in sheet metal work was called in to make devices that would retain or increase the self-cleaning tendencies of the pool and at the same time prevent the fish from escaping. With the aid of his expert work and ideas we soon had several kinds of self-cleaning outlets, two of which are worth describing. Both kinds have the same basic principle of operation, consisting of increasing the suction at the bottom with a metal cylinder placed about the outlet pipe with its top above the water level and its bottom close to the bottom of the pool. This cylinder forces the water through its bottom, while the fish are kept out by a screen of metal leaves arranged concentrically and spaced equidistant apart with edges only to the current. The leaves were three inches deep and spaced according to the size of the fish which it was desired to keep in the pool. Ordinary screen of any size is unsuitable for use in the cylinder, but perforated non-corrosive metal may be used but the arrangement of concentric leaves is more efficient though more expensive. The outside and inside cylinders are kept equidistant apart by three pieces of metal three inches deep soldered at the ends to the outside shell and top of the inner cylinder. This kind of device has been adapted to use in the hatchery trough.

The second type of self-cleaning device is illustrated in figures 1, 2, 3. In this type the water leaves the pool between the bottom

edge of the outside cylinder (Figure 2, left) and the side of the sloping cone-shaped bottom (Figure 2, right) which is the base of the sleeve which fits over the outlet pipe. The escape of fish from the pool is prevented by regulating the size of the aperture about the cone base with a rod threaded on the end and attached either to the outside or inside of the outside cylinder (See Figure 1). The end of this rod is inserted in a nut soldered upon the cone-shaped base, and as the handle of the rod is turned clockwise, the outside cylinder is lifted away from the cone-shaped base.

The circular pools at the Leetown station have been equipped with the latter type of outlet. The dimensions of the device are as follows: Height of outside cylinder, 24 inches; diameter of outside cylinder for circular pools with three-inch outlet pipes, seven inches, for pools with two-inch outlet pipes, five and a half inches. The rod guides on the outside cylinder are of 3½ by ¾ by ⅛-inch wrought iron, the ¼ inch rod hole of the lower guide is threaded while the upper guide is unthreaded. The rod for adjusting the size of the aperture through which the water leaves the pool is made from 33 by ¼ inch brazing metal. The inside cylinder is 16 inches long and extends through the cone-shaped base to the bottom of which it is soldered. It is two and a half inches in diameter for two-inch outlet pipes and three and a half inches for three-inch outlet pipes. The cone base is eight inches in diameter and one and a half inches in height and made of two pieces, the cone and a bottom piece.

A nut is soldered onto the side of the cone base as illustrated in figure 1, or set on the base of the cone inside. The threads on the inside of the nut are reamed out so that the tip of the rod merely turns in it. In more recently improved devices the end of the rod is split for a quarter of an inch from the tip of the rod and soldered so that the rod can not be pulled from the nut when the cleaning device is lifted.

The walls of the outside cylinder are kept equidistant from the inside cylinder by six short rods (length about two inches) set in two groups of three each at distances of one and a half and twelve and a half inches from the bottom of the outside cylinder (See Figure 3, right). These short pieces are made of one-fourth inch brazing metal. They are threaded on the end that extends through the outside cylinder wall and two nuts are used (one inside and one outside) to lock the rods to the cylinder wall and make them rigid. The ends adjacent to the inside cylinder wall are free and in light contact with the cylinder.

Most of our circular pools, all with dirt bottoms, have been in operation for a sufficient period to observe effects of erosion by fish and the circulating water upon them. Good circulation can be maintained by providing a concrete curb at the water's edge, which

also prevents grass from growing along the crests of the banks, an objectionable feature. It has been found advantageous to place gravel in the bottoms of the pools in order to prevent erosion of pockets and holes by the fish.

There have been periods when filamentous algae have developed in considerable abundance in the circular pools causing the screens to clog more rapidly. It was found that these growths could be stopped by hanging small bags of copper sulphate crystals in the water. In 12, 15, and 22-foot pools, all receiving from 10-12 gallons of water per minute, 12 grams of the large (unpulverized) crystals are used for the first two sizes of pools and 15 grams for 22-foot pools. The bags may be tied on the inner edge of the supply pipe or at any point along the outside edge of the pool where water from the supply pipe can not spray directly against it. The same copper sulphate treatment applied at weekly intervals has been used in the prevention of bacterial gill disease. The treatments are not used continuously, but only during epidemics.

Sterilization of a circular pool after an outbreak of bacterial gill disease, for example, can be accomplished quickly and very cheaply by the use of chlorine gas. A chlorine gas tank has been fitted with a galvanized pipe of small diameter lined with rubber (rubber tube) inside. The chlorine tank is supplied with an extra valve for quickly cutting off the flow of gas which is introduced at the bottom of the pool. The gas is allowed to bubble into the pool until a half ounce (15 ml.) sample of the pool water gives a very definite yellow color when ten drops (0.5 ml.) of ortho-tolidine solution (for chlorine testing[1]) is added from a medicine dropper. A pool can be sterilized in five minutes without shutting off the water by this method. It can be immediately drained and refilled or allowed to stand overnight when all chlorine will have disappeared of its own accord.

Recent experiments have shown that fish with bacterial gill disease can be treated in the circular pool without any handling whatsoever or cutting off the water supply by introducing quickly chlorine gas until a yellow color to ortho-tolidine (as above) indicates that a concentration of about ½ parts per million of chlorine are present. After the fish are exposed for a minute and a half, a pint (500 ml.) of N/5 sodium thiosulphate, or "Hypo," diluted with a quart of water (1,000 ml.) is poured into the pond. This neutralizes all chlorine almost instantaneously as shown by samples taken afterward.[2]

Chlorine gas is poisonous, as most germicidal agents are, and care when using a gas tank should be taken not to inhale large quanti-

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[1]The ortho-tolidine solution for chlorine testing can be purchased ready for use from the La Motte Chemical Products Company, Baltimore, Maryland.

[2]The application of the method of using chlorine gas from a tank has not yet been perfected to the point where the layman, without some knowledge of chemistry, can use it. Perfection of the method awaits the trial of suitable meters, valves, or pressure gauges which will show just how much gas has been introduced into a pool.

ties of the gas. Its presence at any point will make itself known by its irritability. Although members of our own personnel have not been injured in any manner while using gas tanks, users might be given additional safeguard by wearing a mask which can be purchased for about three dollars.

A more practical and perhaps safer methods of treating fish with chlorine in circular pools has been worked out with high test hypochlorite—the "HTH" of the Mathieson Alkali Works (Inc.), 250 Park Avenue, New York City. This brand of calcium hypochlorite contains 65 per cent of available chlorine and is readily soluble in cold water. By calculation only 0.00377 grams of this compound per gallon of water is required to yield one part per million of chlorine. In practice, however, two to four times that quantity is required, usually four times the amount. For example; about 15 grams (one half ounce) of HTH is required to quickly produce 1.0 parts per million of chlorine in a circular pool 15 feet in diameter and 18 inches deep, whereas 3.4 grams was the calculated amount for 900 gallons of water. A 22 foot circular pool, 28 inches deep required 20 grams of the hypochlorite to produce 1.0 p.p.m. of chlorine. Twenty grams of HTH introduced into a circular pool 12 feet in diameter and 18 inches deep yielded 2.4 parts per million which is near the upper limit of the quantity of chlorine which should be used for a two minute treatment.

The amount of calcium hypochlorite (HTH) required to produce from 1-2 p.p.m., (a strong yellow color) when 0.5.c.c. of ortho-tolidine is added to a 15 ml. sample, in a circular pool can be determined by experiment. The Leetown pools require about the following:—12 foot pools, 18 inches deep—12 grams; 15 foot pools 18 inches deep—15 grams; 22 foot pools, 18-28 inches deep—20 grams.

The calcium hypochlorite, which should be kept in air-tight glass containers (we use fruit jars), is weighed out carefully and dissolved is about 2/3 quarts of cold water. During the solution process, a white curd is formed in the solution due to the precipitation of calcium carbonate. The solution is added to the circular pool by emptying the container with the 2/3 quarts of solution in walking once about the pool. After 30 seconds has elapsed 10 drops of ortho-tolidine solution is added to a half ounce sample from the pool. If a strong yellow color appears after a few seconds, it is known that sufficient chlorine has been added for destruction of the bacteria on the gills of the fish. If the sample gives a brownish or red color, sufficient N/5 sodium thiosulphate solution should be added immediately to neutralize the chlorine. If the reaction produces a relatively strong yellow color, the fish may be exposed 1.5 -2.0 minutes, time being taken from 15 seconds after the hypochlorite solution has been added. Then 500 ml. of N/5 sodium thiosulphate solution is diluted with three or four times its volume of water and the container emptied into the pool by walking about the

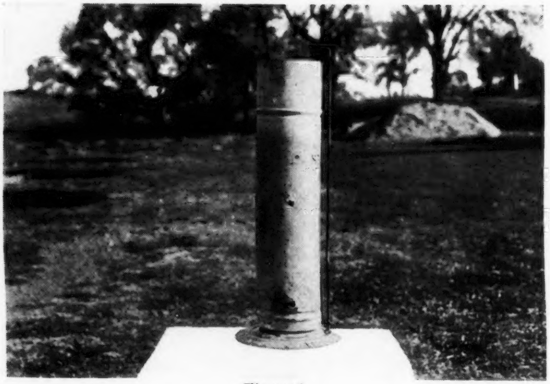

Figure 1

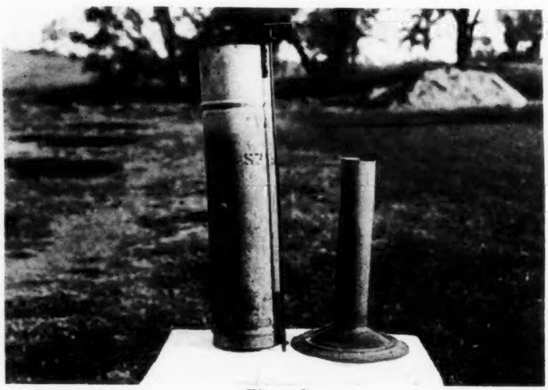

Figure 2

Figure 3

SELF-CLEANING DEVICE FOR CIRCULAR POOLS

NOTE: Since this photograph was taken, the device has been further improved by putting a bottom into the cone-shaped base.

pool once, pouring on the way around. Neutralization begins two minutes and 15 seconds after the hypochlorite solution is added. Two or three samples of water should be taken from the pool after the chlorine is supposedly neutralized and tested as before to make sure that all chlorine has been neutralized. If not, add from 200 to 500 ml. more of the sodium thiosulphate solution prepared in advance and kept at hand during the treatment.

The common method of treating fish with bacterial gill disease is that recommended by Davis (1929, p. 160) in which the infected fish are dipped in a 1 to 2,000 copper sulphate solution. However, in handling a large number of fish, as is usually necessary with circular pools, special precautions with the dipping solution must be taken to avoid unnecessarily weakening the fish, also, to preserve the strength of the dipping solution.

When the trout are dipped, they are usually allowed to remain in the copper sulphate solution in a painted tub for one minute. During this time they are removing oxygen from the water, and it takes but a few dips to seriously deplete the oxygen supply. Therefore, the first precaution is to assure plenty of oxygen by aerating the water after each dip or during the dipping process. It is believed that many more fish can be killed by failure to aerate the copper sulphate solution than is killed by the chemical itself.

The chemical nature of water supplies at different stations undoubtedly varies considerably. At the Leetown station the water has a hardness of about 463 parts per million and a methyl orange alkalinity of about 285 parts per million. When copper sulphate is added to it in making a dipping solution, the copper ions begin immediately to precipitate out as copper hydroxide, visible as a blueish white curd which soon clouds the water so that the bottom of the tub can not be seen. A study of this precipitation has shown that in standing nine minutes the strength of the copper ions active in destroying bacteria had been reduced 64.95 per cent. Even though the remaining 35.05 per cent concentration might be sufficient to destroy most of the bacteria, the avoidance of the precipitation may mean the difference between one and two dips in destroying all bacteria.

It was found that the addition of a very small quantity of 99 per cent or "glacial" acetic acid prevents the precipitation just described, and at the same time does not form other insoluable copper compounds. In practice we are now using a 50 quart dipping solution to which one ounce of copper sulphate and 10 ml. of 99 per cent glacial acetic acid are added. This solution is clear and effective.

LITERATURE CITED

Davis, H. S.

1929—Care and diseases of trout. Appendix IV to the Report of the U. S. Commissioner of Fisheries for 1929, Bureau of Fisheries Document No. 1061, pp. 119-171.

THE PRACTICAL VALUE OF DETERMINING THE FERTILITY OF WHITEFISH EGGS

E. L. Wickliff, Chief

Bureau of Scientific Research, Ohio Division of Conservation

At the 1931 meeting of this Society I summarized our experimental work on the technique of fertilizing whitefish eggs. Today I shall review the results of our fertility tests of whitefish eggs since 1925 at the State Fish Hatchery, Put-in-Bay, Ohio, and point out several of its practical features. A fertile egg in this paper is one in the two-cell or other cleavage stage of development. Throughout the eight years of testing whitefish eggs the writer has been assisted by, and received helpful suggestions from Mr. Harry C. Crossley, Chief of the Bureau of Lake Erie Supervision; Mr. George F. Miller, Superintendent of the State Fish Hatchery at Put-in-Bay, and his hatchery assistants, and Mr. Robert Shortliff, Captain of the State Boat "Investigator." Without the cooperation of these men and the commercial fishermen the work would not have been possible.

The whitefish eggs were taken by commercial fishermen, largely in the vicinity of Kellys Island and South Bass Island, who are licensed by the state. The method is described in bulletin number twenty-eight of the Ohio Division of Conservation entitled "Artificial Propagation of Fish." From sixteen to forty-eight hours after the eggs were fertilized they were examined in the hatchery, unless otherwise mentioned, by the use of a binocular microscope. At this time they are in the early cleavage stages of development. By means of a hollow glass tube about eighteen inches long, from thirty to one hundred eggs were taken from each jar and used as a sample. Such a sample included eggs throughout their vertical depth in the jar. The eggs were immediately placed in a Syracuse watch glass, covered with water, examined with the low power of the microscope, and turned with a toothpick to determine their fertility. During early cleavage stages it is necessary to turn each egg as the germ attached to the top of the yolk and oil globules floats freely in the perivitelline space (water bag) and in this position cannot be seen with the microscope. Water temperatures were obtained from hatchery records and air temperatures from the Sandusky weather bureau. All temperatures were the highest

recorded for the day, because at higher temperatures they appeared to show more critical conditions.

From 1919 to 1928 the state paid the commercial fishermen fifty cents a quart for green or fresh eggs, after they were fully swelled. Since 1929 payment has been on a fertility or eyed egg basis; in 1929 and 1930 at the rate of seventy-five cents per quart for eyed eggs; in 1931, three-fourths of one cent for each one per cent of fertile eggs per quart of green eggs received each day; in 1932 sixty cents per quart for eyed eggs. The eyed eggs were measured about the middle of February.

On November 4, 1925, eggs taken by two spawn takers showed a difference of eighty-two per cent in fertility. One fisherman's eggs averaged fifteen per cent fertile and the other ninety-seven per cent. On November 10 eggs from two fishermen averaged sixty and eighty-two per cent fertile, respectively.

On November 9, 1926, eggs from six commercial fishermen showed a difference in fertility of sixty-nine per cent. Eggs taken between November 10 and 17 showed similar differences in fertility.

Between November 18 and December 5, 1927, the eggs ranged in fertility from five-tenths of one per cent to fifty-three and one-tenth per cent. Samples from 348 jars representing twenty-six spawn takers and totaling 17,000 eggs were examined in the embryo stage between December 15 and 19. The average fertility of 348 tests of 1,218 quarts of eggs was twenty-one and five-tenths per cent; the total number of quarts taken was 4,276. This same fall a series of experiments were started to determine the technique for properly fertilizing whitefish eggs, and before the fall whitefish season of 1928 opened we issued printed instructions to all spawn takers, and Mr. Robert Shortliff instructed the fishermen in this work.

During the fall whitefish season of 1928 the writer had the first opportunity to follow through the fertility of eggs handed in daily by two spawn takers. Table 1 shows high air temperatures 14° C. (57° F.) to 21° C. (70° F.) and high water temperatures 9° C. (48° F.) to 10° C. (49° F.) between November 16 and 18, but with decreasing air and water temperatures after these dates, except on November 30 when the air temperature was 12° C. (53° F.). These temperature changes seem to be correlated in some way with whitefish egg fertility. Between November 16 and 18 the fertility was not above eleven per cent but with the lowering of air and water temperatures a high point of eighty-six per cent was reached on November 27. After this date the fertility fluctuated widely but was never below fifty-five per cent. A low water temperature of 4° C. (39° F.) persisted during most of the period of fluctuating air temperatures.

TABLE 1. SHOWING AIR AND WATER TEMPERATURES, NUMBER OF QUARTS OF WHITEFISH EGGS TAKEN AND PERCENTAGE FERTILE EACH DAY OF THE MONTH, BY YEARS

	1928				1929				1930				1931				1932			
	Air	H_2O	Qts.	%	Air	H_2O	Qts.	%	Air	H_2O	Qts.	%	Air	H_2O	Qts.	%	Air	H_2O	Qts.	%
Nov.																				
8									59	42	**	68								
9											*									
10									57	43	18½	76								
11					53	46	9½	75.2	56	44	26½	70								
12					51	46	**	83.5	58	44	29	57								
13					49	46	19	65	60	44	93	70								
14					49	46	51½	49.7	59	44	76	63					56	43	**	68
15					52	46	59½	74.7	65	45	109	15					47	44	19	88
16	63	49	96	11	49	46	76½	77.7	68	45	172½	26					36	40	**	94
17	70	49	62	0	46	46	77½	69	66	45	120½	46	72	50	13½	2.6	39	40	37	89
18	57	48	59	7	46	46	59½	89.6	63	45	503	38	63	49	2½	1.4	39	40	89	84
19	43	47	182	12	41	45	111½	82.3	58	45	171	24	57	49	13	4.2	36	40	83	78
20	40	46	103	65	37	44	154	92.6	72	46	500	11	73	51	7	5	41	39	90	91
21			*		31	43	241	88.4	67	46	513	15	69	50	27	3.2	40	39	462	92
22	42	45	219	52	28	42	196	90.4	46	44	484½	83	60	50	66½	6.7	36	38	247	91
23	40	44	241	75	38	41	259½	92.2	55	44	202½	76	74	50	23½	13.8				
24	46	43	182	58	36	41	248	90.6	46	43	198½	72	68	50	114	10.9				
25			*		46	40	392½	91			**		39	47	32	52.9				
26	36	40	438	84	50	40	201	88.8	30	40	235	82	37	48	10	33.8				
27	42	39	358	86	44	40	359½	87.4					36	47	102	39.4				
28	39	39	412	83									38	47	31	61.5				
29	42	39	294	69									36	46	100	38.3				
30	53	39	461	63									41	45	68	46.3				
Dec.																				
1	38	39	230	82									38	44	121	57.2				
2	43	39	214	76									43	44	121	72.3				
3	46	39	273	68									49	44	505	81.2				
4	42	39	210	81									42	44	249½	71.9				
5	34	39	248	57									38	43	227	72.9				
6			*										39	42	116	73.4				
7	32	36	145	84									34	41	210	79.7				
8			*										31	40	262	82.2				
9	35	36	147	55									43	40	300	86.3				
10													45	40	120	85.9				

Temperatures are expressed in Fahrenheit degrees.
*No record of eggs received.
**Number of quarts of eggs not available.

In 1929 (Table 1) the results were more conclusive. Over 700 jars of eggs were examined from ten spawn takers. The eggs were taken between November 9 and 29. Low air and water temperatures prevailed during the entire spawning period and this is reflected in the high fertility of the eggs (sixty-five to ninety-three per cent, except November 14). On this date the low fertility of fifty per cent was due to four spawn takers handing in eggs ranging from twelve to thirty-five per cent fertile. Between November 18 and 27, when most of the eggs were taken, the average daily fertility ranged from eighty-two to ninety-three per cent, a record the fishermen may be proud of.

The most interesting year of the five-year period (1928 to 1932) was 1930. Table 1 shows medium low water temperatures 6° C. (42° F.) to 7° C. (44° F.) during the early part of the season (November 8 to 14); a medium high air temperature 13° C. (56° F.) to 16° C. (60° F.); and a medium high fertility (fifty-seven to seventy-six per cent). From November 15 to 21 the air tempera-

tures were high 14° C. (58° F.) to 22° C. (72° F.); water temperatures medium high 7° C. (45° F.) to 8° C. (46° F.); and fertility low (eleven to forty-six per cent). During this period 2,089 quarts of whitefish eggs (83,560,000) out of a total of 4,107 for the season, ranged in fertility from eleven to seventeen per cent. This represents a loss of millions of potential baby fish. Between November 22 and 26 the air and water temperatures dropped rapidly while egg fertility jumped in one day from an average of fifteen per cent on November 21 to eighty-three per cent on November 22. A reverse effect is observed on November 14 and 15 when the fertility fell from sixty-three per cent to fifteen per cent, with rising air and water temperatures. The above results seem to be significant because of the rather close correlation between medium to low air and low water temperatures, and medium high fertility, the first and third weeks of the breeding season. The low fertility the second week is correlated with high air and medium high water temperatures. During the three-week spawning season 306 tests were made of eggs from nineteen spawn takers.

In 1931 3,129 quarts of eggs were received and of this number 676 jars of eggs from nineteen spawn takers were examined. The first week eggs were received (November 17 to November 24) was characterized by high air and water temperatures. The air temperatures ranged from 14° C. (57° F.) to 23° C. (74° F.); the water from 9° C. (49° F.) to 10° C. (51° F.) (Table 1). Correlated with these high temperatures the average fertility was not above fourteen per cent. Between November 24 and 25 the air temperature was reduced from 20° C. (68° F.) to 4° C. (39° F.) and the water temperature was lowered from 10° C. (50° F.) to 8° C. (47° F.). Correlated with these temperature reductions the whitefish egg fertility in one day increased from eleven to fifty-three per cent. As the season progressed air and water temperatures continued to fall while fertility increased, ranging between seventy-two to eighty-seven per cent from December 2 to 10. Tests of 111 jars of eggs taken by twenty spawn takers for the Federal Hatchery showed similar results. Most of the eggs did not harden normally but were somewhat soft and rubbery.

From the standpoint of high whitefish egg fertility the first half of the 1932 spawning season was the best the writer has experienced in his eight years of testing whitefish eggs. The season was characterized by low air and water temperatures, except an air temperature of 13° C. (56° F.) on November 14 (Table 1.). The average daily fertility from November 15 to November 22 ranged from seventy-eight per cent to ninety-four per cent. Eggs from thirteen spawn takers examined between November 15 and 22 averaged eighty-eight per cent fertile and tests were terminated on November 22, due to the excellent quality of the eggs. A total of 7,111 quarts of whitefish eggs were received.

SUMMARY

1. Fertility tests of whitefish eggs were made at the State Put-in-Bay Hatchery for the past eight years and at the Federal Hatchery in 1931.

2. The daily relationship between egg fertility, air and water temperatures and number of quarts of eggs for the past five years, indicate a rather close relationship between high egg fertility, low water and air temperatures; between low water and air temperatures and total number of quarts of eggs received, except November 18 to 21, 1930. Low air and water temperatures are correlated with high fertility, if the technique outlined on pages 205 and 206 of the Transactions of the American Fisheries Society for 1931 is followed. Low water and high air temperatures are not favorable for high fertility unless the eggs are kept cool. Since 1918 State hatchery records indicate that fertile eggs have not been taken by commercial fishermen with a water temperature above 11° C. (52° F.), and it does not seem advisable to allow the water temperature in the spawn keg to exceed this temperature at the western end of Lake Erie; 4° C. (40° F.) to 7° C. (45° F.) is better, especially if the air temperature is below 10° C. (50° F.). Low water temperatures, down to the freezing point, did not seem to influence fertility.

3. A microscope in the hatchery will allow the superintendent or other hatchery employee to examine the eggs sixteen to forty-eight hours after they are fertilized (early cleavage stages). If the fertility is not up to normal he can notify the spawn taker immediately and offer suggestions for improving the quality of the eggs. During the past few years we have followed this system with very good success. Details on the value of the microscope in a fish hatchery will be found in the 1898 Proceedings of the American Fisheries Society, pp. 88-93, in an article by J. J. Stranahan entitled "The Microscope as Practically Applied to Fish Culture."

4. Under the present system of paying for eyed or fertile eggs in Ohio (Section 1447) the fishermen do not receive payment for infertile eggs and it is to their advantage to use the proper technique in fertilizing and handling the eggs because the pay check for such eggs is regulated by their quality and not by quantity. From the standpoint of conservation, quality of the eggs is the major consideration for allowing the fish to be caught during the spawning season. Infertile eggs do not produce any more baby fish than eggs sent to the market with the fish.

5. Other causes for low fertility, exclusive of technique and high temperatures, are:

a. Small or unripe eggs. Such eggs may not swell and, therefore, do not have the characteristic water bag.

b. Ruptured yolks.

c. Normal eggs not fertile may be caused by:

1. Insufficient milt.

2. Eggs flat sided. This may be due to crowding and insufficient water.

3. Adverse weather conditions, such as rough weather.

4. Soft eggs.

5. In a few cases the fertility is reflected in the type of gear used or in the individual taking the spawn.

6. The commercial fishermen of Ohio are to be congratulated for the excellent quality of their whitefish eggs. Eggs received from Kellys Island and Put-in-Bay average higher in fertility than Sandusky eggs.

7. Each spawn taker should be encouraged to look through a microscope so that he can see why it is necessary to use technique in fertilizing and caring for whitefish eggs.

Discussion

MR. RODD (Ottawa, Ont.): Did you associate the improved quality of the eggs as the season advanced with the improved technique on the part of the spawn takers?

MR. WICKLIFF: I think the results of 1927 indicate that something was wrong with the quality of the eggs throughout the spawning season. We noted a better class of eggs coming in after instructions were issued to the fishermen (fall of 1928), and especially after we sent one of our men, a practical spawn taker, in the field to show the fishermen the better method of taking eggs. If we are going to pay for eggs I am quite sure, as a result of the eight years we have been working on these eggs, it should be on a fertility or eyed egg basis, because you are paying for quality, not quantity. Quantity may not produce whitefish to put in the lake; quality will.

MR. WEBSTER (Wisconsin): I would like to inquire if any effort has ever been made by the state of Ohio to determine the fertilization of eggs that are laid naturally on the bottom of the lake.

MR. WICKLIFF: We tried it two years ago, using a pump, but unfortunately we did not take a single egg from the bottom of the lake. I believe the Ontario people under Dr. Harkness found that whitefish eggs fertilized naturally had a very high percentage of fertility. Perhaps Dr. Harkness or one of his men can explain it.

DR. HARKNESS (Ontario, Canada): Just offhand I could not even give you a close estimate of the percentage of fertility, but J. L. Hart carred on a study and has reported on it in the Transactions of the Biological Board of Canada, and if you are interested I can send you a reprint of his paper.

MR. WEBSTER: I should be very glad to have it.

DR. HARKNESS: He carried on these investigations for only one season, and that was all that our financial support would allow us to do. Perhaps the results from one season are not worth while, but they are at least significant to this extent: although he found a high percentage of whitefish eggs fertilized, the natural predators on the natural spawning grounds were

very destructive. Yellow perch in particular destroy actually millions of them. I suppose counts were made in perch stomachs as well as various other predators, but the yellow perch in these particular spawning beds were the worst enemy of the whitefish.

MR. WICKLIFF: Along the same line I would like to make another point that will be taken up tomorrow in one of our other papers. As part of our hydro-biological and fishery survey of the western end of Lake Erie in 1928, we used meter nets, Helgoland and Peterson trawls to collect larval, post larval and young fish over their natural spawning grounds. On several occasions we followed our state boat, as they were liberating the fry, outside their natural spawning grounds. Then we went to the natural spawning grounds of the whitefish around Kellys Island. No whitefish had previously been planted in 1928 at Kellys Island, and we took just as many whitefish on the natural spawning grounds as we did following right back of the boat planting fish. Unpublished data for 1928 and 1929 show large numbers of baby fish of several commercial species over their natural breeding areas and where hatchery fish were not planted.

THE PROGRESS OF THE COOPERATIVE FISH PROPAGATION AT ROCHESTER AND MONROE COUNTY, NEW YORK

Henry C. Markus
United States Bureau of Fisheries

In May, 1932, a cooperative agreement was made between the United States Bureau of Fisheries and the City of Rochester, New York, whereby the City of Rochester turned over its city park lakes to the Bureau of Fisheries for the purpose of propagating bass. The parks of the City of Rochester contain about twenty-five acres of water divided into a number of ponds well adapted for propagating bass after suitable drains are put into these small bodies of water. They vary in size from two to five acres. The city has agreed to construct drains so that the ponds can be completely drained and any further construction necessary for the rearing of bass. The Bureau of Fisheries agrees to operate these ponds without any expense of operation to the city. When the bass are ready for distribution they are turned over to the city and released in waters designated by the State Survey in the immediate vicinity of Rochester, New York.

In the spring of 1932 shortly after the agreement was made it seemed as if the cooperative project was to fall by the wayside, due to government curtailment of expenses. The aid of the New York Conservation Department was sought and they agreed to cooperate, thus making the project a triple affair. The project was then carried through the season, in spite of the late start, with reasonable success.

Uncertainty as to how financial matters were to be met delayed the process of getting a suitable start in the spring. However, one pond, known as Trott Lake, with an approximate area of two and one-half acres, was put into operation. The pond was stocked rather late with large mouth bass breeders. The following August 22,204 three inch fingerlings were taken from this pond. Thus a yield of approximately 8,882 fingerling bass was obtained per acre.

The process of preparing other ponds during the summer for propagating bass for the following season was halted by cries of economy and we were informed by the Department of Conservation that they would be unable to go along with us any further, due to the lack of funds. The following fall, light was again seen when the work relief bureau for the unemployed came into existence and revived the project.

Through the work relief the city is now preparing the ponds so that they will be ready for rearing bass the coming spring and also constructing new pools. These are being built in the ravines of the parks by damming off the ravine. These dams are fills over which roadways are built through the park.

In the meantime the County of Monroe, of which Rochester is the county seat, became interested in the project and the County Park Commission agreed to develop any available location that would adapt itself for propagating fish. A survey was made and it was found that they had a fitting location for a trout hatchery in one of its parks known as Powder Mill Park. The water supply, which is furnished wholly by springs that can be kept free from contamination, has a constant temperature of 48 degrees F. and a uniform flow throughout the year. The hatchery is a modern plant and built with the aim of growing fish to legal size before they are planted into the streams. It consists of a building with twelve hatching troughs, meat room, work room and an attic for storage. The rearing pools on the outside consist of five circular pools twenty-five feet in diameter, twelve rectangular pools sixty feet long and seven feet wide and two larger pools walled with rocks and the bottom covered with gravel with an area of approximately one-third and one-half acres, respectively. The layout is large enough so that we will be able to liberate at least 50,000 trout between seven and twelve inches in length annually. The hatchery is being built by the county through relief labor.

In another of the county parks known as Mendon Ponds Park the county is now constructing ponds for the purpose of rearing bluegill, crappie, bullheads and forage fish.

Forage fish will be reared in both county and city parks for planting in waters to be stocked with game fish in order to supplement the natural food supply in those streams.

The Bureau's interest in the project was stated by O'Malley (1932: 353). "The Bureau has also furnished a man to take charge of an unique experiment in community fish rearing at Rochester, N. Y. The public parks in the vicinity of that city afford unusual opportunity for the propagation of pond fish, and there has been developed in cooperation with the New York Conservation Department, city authorities and the Izaak Walton League a plan to use this area as a laboratory for demonstrating how communities can be self-sufficient in producing fish for their own territory."

The author was interested in an article by Robert Page Lincoln appearing in the magazine, "Sports Afield" (August, 1933: 23), "While it is doubtful if the game and fish authorities of the various states give any aid to these individual or community bass-pond activities it is possible that such sources may be drawn upon for advice, and sometimes even personal supervision. To date there

has been a universal feeling of 'let George do it,' which means that individual efforts have been disregarded, the game and fish departments being loaded down with the responsibility of keeping the fish supply at top notch. It has been found to be true, however, that these departments have been so crowded with this work that they have been unable to cope with the overwhelming demands made upon them. It will be found that unless individual efforts, and especially community efforts, along these lines are not carried out in the future the fish supply will be slated for oblivion. Probably some game and fish commissions oppose these individual efforts, and resent what may seem to be a 'butting in' on their work. Only by going into the matter and doing some active investigation here and there throughout the country can the truth of this be ascertained." Mr. Lincoln probably never reads the "Transactions of the American Fisheries Society" or he would have read the citation made by O'Malley of the community fish rearing project in Rochester, New York, and the accomplishments of Tulsa, Oklahoma. The author fully agrees with the above quotation as to the extent which communities may aid in the propagating of fish, but was unable to find any lack of cooperation as far as the Bureau of Fisheries and State Department of Conservation was concerned in the State of New York. Instead the United States Bureau of Fisheries, State Conservation Department, the County of Monroe and the City of Rochester are willing to cooperate in every way to produce more fishing for the sportsman.

LITERATURE CITED

Lincoln, Robert Page, 1933, Large Mouth Black Bass. Sports Afield, 1933: 23.

O'Malley, Henry, 1932, The American Fisheries Society and the Fisheries, Trans. Am. Fish. Soc., 1932: 351-345.

Discussion

Mr. LeCompte (Maryland): What species of fish are propagated at the hatchery?

Mr. Markus: Rainbow and brown trout. We have no really suitable brook trout water in that vicinity.

Mr. LeCompte: Are these ponds fed by artificial process or by natural spring water?

Mr. Markus: They are all supplied with spring water. There is practically no watershed.

Mr. LeCompte: It is not piped in from the city water supply?

Mr. Markus: No.

Mr. LeCompte: Are they drainable?

Mr. Markus: Yes, they will be constructed so that they will be drainable.

The President: This project at Rochester is a most interesting and important one, and may well serve as an example for other communities. It shows what can be accomplished when an enthusiastic lot of anglers get behind a local project.

WATER-FARMING AS EXEMPLIFIED BY THE OYSTER INDUSTRY

LEWIS RADCLIFFE
Executive Secretary, Oyster Growers & Dealers Association of N. A., Inc.

The American Fisheries Society can well be proud of its record in fostering the development of fish-culture in this country and the promotion of scientific research in this field. While many members may think of it primarily as fostering the development of fish-culture as practiced by Federal, State and private agencies for the stocking of waters, the significance of its work is much deeper. It is laying the foundation for the development of water-farming not only of game fishes for sport but the growing of food fishes and other aquatic products to parallel the work of the land farmers. Fifteen years ago we had no yardstick for measuring the productivity of water acres and I for one was skeptical that the production in animal proteins of an acre of water would compare at all favorably with an acre of fertile soil. All that has been changed. We are fast accumulating the scientific facts with which to apply our measuring stick and the evidence we now have clearly indicates that the productivity of water areas compares very favorably with land areas, if it is not actually superior. Those who have followed at all closely the experiments directed by Dr. H. S. Davis at the Fairport, Iowa, laboratory, can find abundant proof of that.

As this Society has had its interest centered chiefly on the production of fresh-water areas, the advances made in the cultivation of oysters is less well known. Yet the beginning of oyster farming in this country date back to a very early period in our history.

As Dr. H. D. Pease (The Oyster-Modern Science Comes to the Support of an Ancient Food, Journal of Chemical Education, Vol. 9 No. 10, October, 1932) points out by 1770, with the growth of population and increased consumption of oysters in the Boston area "it became necessary to prevent their entire destruction, for the district to take measures to preserve and propagate them." By 1775 these beds had become practically exhausted and by 1850, the vast supplies in New York and Connecticut had begun to fail. As a result, each spring hundreds of thousands of bushels were transported by schooner from Chesapeake Bay for transplanting on these exhausted beds for reharvesting for the fall and winter markets.

As early as 1880 this business began to decline largely due to the drain on the supposedly inexhaustable supply in Maryland and Virginia waters.

In 1874, the practice of returning the oyster shells to the oyster bottoms for the collection of a set began in Connecticut. Thus began

the development of the science of oyster farming which has reached a greater stage of perfection than any other water farming industry in this country. Hydrobiologists have been a very important factor in this development and at the last meeting of the society Dr. Herbert F. Prytherch, Director of the Beaufort, N. C. laboratory, gave an account of the "Scientific Methods of Oyster Farming."

One of the great obstacles to water farming has been the difficulty of obtaining ownership or the right to use water areas for farming purposes. In no other branch of water farming has there been such progress in acquiring ownership of water bottoms or the leasing of such areas under terms that would give to the owner or lessee reasonable expectations of reaping the benefits of his own industry as in the oyster industry. While this has been accomplished only by the patience and perseverance of the oyster farmer, the difficulties are still so great in many states that it constitutes the chief retardant to the further development of the industry. This problem is so momentous in hindering the development of water farming everywhere, that I believe this Society might well appoint a standing committee to study this subject and report its findings and recommendations year by year in order that this hindrance may be alleviated. I believe this could well be made one of the most constructive activities of this Society.

Several years ago I undertook to determine the total acreage in United States waters producing oysters. These estimates showed a total of 13,250,000 acres of which about 347,000 had been affected by restrictions or rendered wholly useless. As some of this acreage is used for seed purposes or for subsequent transplantation to good producing areas, we may estimate the area of bottoms growing oysters at about one million acres. That includes highly productive acres and poor acres as well.

On the basis of one million acres, production of oysters per acre in 1928 was 155 pounds; in 1929, 152 pounds; in 1930, 125 pounds and in 1931, 101 pounds or an average of 133 pounds per annum.

For a comparison with a comparable production of land areas, I have taken a rough average of various crops for several years as reported in the Department of Agriculture Yearbook as follows:

Beef	**140**	**lbs. per acre**	**@ $ .06 per lb.**	**$ 8.40**
Wheat	**800**	**lbs. per acre**	**@ 1.00 per bush.**	**13.33**
Pork	**300**	**lbs. per acre**	**@ .05 per lb.**	**15.00**
Cotton	**160**	**lbs. per acre**	**@ .10 per lb.**	**16.00**
Corn	**1700**	**lbs. per acre**	**@ .70 per bush.**	**20.30**
Peas	**1222**	**lbs. per acre**	**@ .03 per lb.**	**36.66**
Tomatoes (canning)	**4.15**	**tons per acre**	**@ 11.00 per ton**	**45.65**
Potatoes	**110**	**bush. per acre**	**@ .50 per bush.**	**55.00**
Sugar Beets	**10**	**tons per acre**	**@ 6.00 per ton**	**60.00**
Onions	**308**	**bush. per acre**	**@ .60 per bush.**	**184.80**

These are cultivated crops for which scientific methods of increasing production have been the subject of a great deal of study, whereas the production figures for oysters previously used included an estimate of all classes of areas in which oysters grow, whether cultivated or uncultivated, on good or poor growing grounds, well stocked and poorly stocked or practically barren bottoms.

To obtain a closer approximation of the productivity of an acre of oyster bottom let us take 1930 production figures for Connecticut and Rhode Island where we know with greater definiteness the acreage and where oyster farming is well developed. The production per acre was 225 pounds, at the average purchase price of 16c per pound received by the producer totaled $36.00. If we had the exact facts which would enable us to weed out the unproductive, uncultivated areas, we are confident that the yield per acre was not less than $50. Then too, large areas in Connecticut are devoted to seed production. In New Jersey the yield was nearly 470 pounds at 14c a pound, yielded $65.80 per acre. While these figures fall far short of revealing the maximum production of market oyster grounds, they compare very favorably with the higher yield farm crops.

In this connection it is important to remember the amount of labor involved in cultivation, transplantation, harvesting and warding off the enemies of the oysters and the time period of 4 to 6 years for the crop to reach maturity. One must know oyster farming in detail to succeed and must acquire good grounds. Certain bottoms have been found especially suitable for seed production. After thoroughly dredging old shells, debris and the natural enemies of the oyster, thus cleaning the bottoms, from 500 to 1,000 bushels of old shells per acre are planted on these grounds just prior to the spawning of the oysters to serve as a clean solid place for the young larval oysters to set. If these shells are in danger of being buried or washed ashore during the following winter, they are transplanted to the growing grounds in the fall, otherwise they are left till the following spring. As a rule growing grounds are located in deeper water where no oyster set is obtained. This removes the danger of overcrowding from a growth of young oysters. In from 2 to 5 years according to locality these oysters reach a marketable size. From six months to 2 years prior to marketing it is customary to transplant these oysters again to maturing grounds for fattening purposes. Each year the grounds must be carefully cultivated to eradicate starfish, drills and other enemies of the oyster.

As illustrative of our degree of dependence on the oyster farmer, the yield of market oysters from private grounds in 1930 was nearly 51,500,000 pounds, as compared with 35,376,000 pounds taken from public grounds. The losses of oyster producing areas in the more thickly populated sections resulting from industrial wastes, etc., make it difficult to determine the stabilizing influence of oyster farming in production. In the Chesapeake Bay area conditions are quite com-

parable, except that Virginia has given encouragement to the development of oyster farming, whereas private capital has received scant encouragement in Maryland. The following figures on the production of market oysters, give some indication of the stabilizing effects of oyster farming:

PRODUCTION OF MARKET OYSTERS IN BUSHELS
1890—1931

Year	Maryland	Virginia
1890	10,450,087	6,074,025
1900	5,685,561	6,067,669
1910	5,497,471	4,406,017
1920	4,547,471	3,225,844
1930	2,307,563	2,859,749

The decline in the catch during this period was 25 per cent greater in Maryland than in Virginia, the catch in Virginia now approximating or exceeding that of Maryland.

Not only has the hydrobiologist contributed much to the development of oyster farming but the food research chemist and the nutrition expert have revealed the richness of oysters in minerals, especially iron, copper, manganese and iodine, as well as vitamins, glycogen and other factors, which make them an important article of diet. These researches show that they are easily digested and extremely valuable in the prevention or cure of certain deficiency diseases. I know of no fisheries group, unless it be the west coast salmon industry, that has given such encouragement to scientific workers and shown such a willingness to make practical application of scientific findings. I mention these things as revealing the advances made by this industry in the development of water farming and the application of scientific research. By the application of similar methods, we may expect the extension of water-farming in other branches of the fisheries especially in the growing of some of the warm water fishes for market. Abundance of food, the long-growing season and other factors should make commercially practicable developments of this character in our southern states. The creation of lakes resulting from the construction of power dams and flood control impounded waters can profitably be used for experiments in this field.

THE CHEMICAL DISINFECTION OF TROUT PONDS

Frederic F. Fish
U. S. Bureau of Fisheries

The need for knowledge concerning the prevention and control of fish diseases has never been greater than it is in this present era of economy when two fish must be raised in the same water which once supported but one. Fish pathologists have contributed a great deal to our knowledge of fish diseases, but there is still much to be learned, particularly concerning better methods of preventing and eliminating diseases among our trout. In this era of circular pools and raceways, our disease elimination is way back in the early days of standard troughs.

Until 1932, the chief method of combatting trout diseases was hand dipping, a method which involves considerable time and labor, and often an appreciable loss of fish. Prior to that year, very little attention was given to the possibilities of preventing diseases by prophylactic measures and activities were confined to eliminating diseases after they had become established.

In 1932, Kingsbury and Embody evolved a method of applying disinfectants directly to a running water supply in a uniform concentration. This method was based on the previous discovery by Hess that prolonged immersion in dilute disinfectants was more efficacious in removing fluke parasites from goldfish in standing water than was the customary short hand dip. The point raised by Kingsbury and Embody that such a prolonged application might profitably be used as a preventative of fish diseases as well as a control marked the birth of a new, and exceedingly important, idea in fish culture.

There is little need to dwell further upon the advantages of such prolonged dipping. Any fish culturist who has been confronted with the necessity of treating fish in a pond by seining and subsequent hand dipping will agree that any piece of apparatus which performs this treatment effectively and yet requires but three minutes to set in operation, is certainly worth consideration.

The apparatus for prolonged dipping, as designed by Kingsbury and Embody, consists fundamentally of a large reservoir containing the disinfectant which drains into a smaller secondary reservoir, the level of which is maintained by a float valve. The rate of flow from the secondary reservoir into the troughs or ponds to be treated is controlled by small cocks.

In the opinion of the writer, a modification of the constant flow syphon described by Gaylord and Marsh in 1912 during their work with thyroid carcinoma of trout is less complicated and equally as satisfactory as the apparatus designed by Kingsbury and Embody.

This constant flow syphon consists of a reservoir containing the disinfectant, on the surface of which is a float bearing a syphon made of glass tubing. It is impossible, and quite unnecessary to lay down any standard dimensions for this apparatus, for the variations in the demands upon it are adequately covered by varying the concentration of disinfectant in the reservoir. A generally handy size for most hatchery requirements is made by utilizing a Fearnow pail—or similar receptacle of approximately five gallons capacity—as a reservoir. If a metal reservoir is used, it is advisable to coat the inner surfaces with asphaltum. A single U shaped syphon made of 4 mm. inside diameter Pyrex glass tubing will adequately treat up to 100 gallons of water per minute at a concentration of 1:75,000 or above. The length of the arms of this syphon should be about 12 and 14 inches respectively. The construction of the float is immaterial. The writer uses a piece of painted wood, 7 x 7 x 2 inches, through the center of which is inserted perpendicularly, a piece of ⅜ inch gas pipe 12 inches in length. The shorter arm of the syphon runs through this pipe and no further support for the syphon is necessary. (See Fig. 1).

Once constructed, this constant flow syphon requires but two calibrations; (1) the capacity of the reservoir in cubic centimeters, and (2) the volume of solution delivered by the syphon determined in cubic centimeters per minute. The first of these calibrations is easily made by marking on the side of the reservoir the height attained by a known volume of water. By filling the reservoir to this mark each time the apparatus is used, no further measurements in this direction are necessary. Hence, the Fearnow pail which when filled to the top of the overflow contains five gallons—or 18,926 cubic centimeters—is convenient to use. The second calibration, namely, the amount of solution delivered by the syphon, may be simply determined by holding a graduated cylinder of sufficient capacity under the discharging syphon for a period of one minute.

When these two figures are known, a series of constants are then derived from the following formula:

$$K = \frac{(R)(3785)}{(D)(S)}$$

Wherein:

K=Constant

R=Capacity of the reservoir in cubic centimeters

D=Final strength of disinfectant desired in tank to be treated. The ratio is not used in this formula, hence 1:50,000 becomes 50,000; 1:100,000 becomes 100,000, etc.,

S=Rate of flow from syphon in cubic centimeters per minute

Each dilution of the disinfectant will obviously yield a different number for K in the above formula, and the value of K should be

determined for at least the following dilutions: 50,000, 75,000, 100,000, 150,000, and 200,000. It is likewise obvious that such constants are only applicable to the calibrated syphon and do not hold true for any syphon delivering a volume different from that of the calibrated syphon. It is, therefore, necessary to calculate a new series of constants for each individual syphon.

After these constants are known, when it becomes necessary to treat the fish in a pond, raceway, or trough, one merely needs to measure the inflow of water into the pond, raceway, or trough in question and multiply this measurement in gallons per minute by the particular constant applying to the desired strength of disinfectant and the product of these two numbers will give the number of grams of the disinfectant which, when dissolved in the filled reservoir, will yield the desired dilution of disinfectant. Accordingly, one dissolves that number of grams (or c.c.'s if the disinfectant be liquid) in the reservoir, fills the reservoir to the calibration mark, starts the syphon draining into the pond, and may, for an hour, forget about the apparatus. (See plates I and II).

As a practical demonstration of the simplicity of this constant flow syphon, consider the circumstances surrounding the treatment of an entire hatchery water supply which was being administered when plates I and II were taken.

The apparatus shown in these plates had been calibrated some two months prior to this particular treatment. As a Fearnow pail was utilized as a reservoir, therefore the quantity (R) equalled 18,926. The syphon in use delivered 275 c.c.'s per minute (quantity (S)). Applying these figures to the formula given above, the following series of constants had been derived:

Dilution Desired	Constant (K)
1:50,000	5.2
1:75,000	3.5
1:100,000	2.6
1:150,000	1.7
1:200,000	1.3

Hence, when it was desired to treat the water supply, which happened at the time to measure 60 gallons per minute, with copper sulphate at a dilution of 1:100,000, it was a very simple matter to multiply 60 by 2.6 and derive the product—156. Accordingly, 156 grams of copper sulphate were dissolved in the reservoir, the syphon started by immersing it in water, and the fish throughout the hatchery were treated. The same method of calculation would apply to any flow of water.

The disinfectants and dilutions recommended by Kingsbury and Embody have been adopted as a basis for prolonged dipping. These dilutions are as follows:

Disease	Disinfectant	Dilution
Bacterial gill disease	Copper sulphate	1-75,000
Fin rot	Copper sulphate	1-75,000
External protozoans	Copper sulphate	1-75,000
(Cyclochaeta, Chilodon,	or	
Costia, etc.)	Potass. permanganate	1-100,000
Gyrodactylus	Potass. permanganate	1-100,000
General preventative	Copper sulphate or	1-100,000
treatments	Potass. permanganate	1-200,000

Time of Treatment—One Hour

In the use of all disinfectants, it must be remembered that these reagents are not only toxic to the parasites, but are also injurious to the fish. The condition of the fish should always be considered in the use of any disinfectant and vigilance maintained for signs of extreme distress in the fish when undergoing treatment. Should such symptoms be apparent, the treatment should be stopped immediately. Furthermore, disinfectants may vary a great deal in their toxicity to fish life in different water supplies, and the exact dilution of each disinfectant which will destroy the pathogenic organisms, and at the same time is not unduly injurious to the fish, must be determined by experimentation in each individual water supply.

A few suggestions concerning the use of the constant flow syphon for prolonged dipping are in order.

All ponds or troughs should be drained to a minimum depth consistent with the well being of the fish immediately before the treatment is started. While it is more expensive, it is more effective to employ a relatively large flow of water through any pond or trough undergoing treatment.

When using copper sulphate in the constant flow syphon, the undesirable precipitation of this reagent in hard waters may, and should be, avoided by adding glacial acetic acid, drop by drop, to the reservoir until the milky precipitate is completely dissolved. No more of the acid should be used than is absolutely necessary to dissolve the precipitate.

As a sterilizing agent for ponds not containing fish, a 1:500,000 solution of a standardized calcium or sodium hypochlorite (such a compound is marketed by the Matheson Alkali Works, New York, under the trade name of "H.T.H.") is recommended. The pond should be filled slightly above the usual water line if possible, and the inflow stopped. It is best to leave the disinfectant in the pond for several hours, or overnight, before administering a thorough flushing with fresh water.

Although the prevention and control of fish diseases is still an open field for work, and prophylactic measures are far from perfected, it is believed that the intelligent application of some means of prolonged treatment and disinfection will result in an appreciable reduction in the loss of fish from diseases, with the accompanying savings of time, labor, and money.

PLATE I

TOP VIEW OF CONSTANT FLOW SYPHON TO SHOW DETAILS OF CONSTRUCTION

The handle of the Fearnow pail is held erect by the clamp on the right side. The ring attached to the left side of the handle acts as a guide for the syphon and prevents the syphon from swinging in strong winds. The clamps are not necessary, although at times, very convenient.

PLATE II

SIDE VIEW OF CONSTANT FLOW SYPHON IN ACTION

Resting on the delivery flume, the constant flow of disinfecting solution drains into the hatchery water supply giving a uniform dilution of the disinfectant throughout the troughs and ponds below.

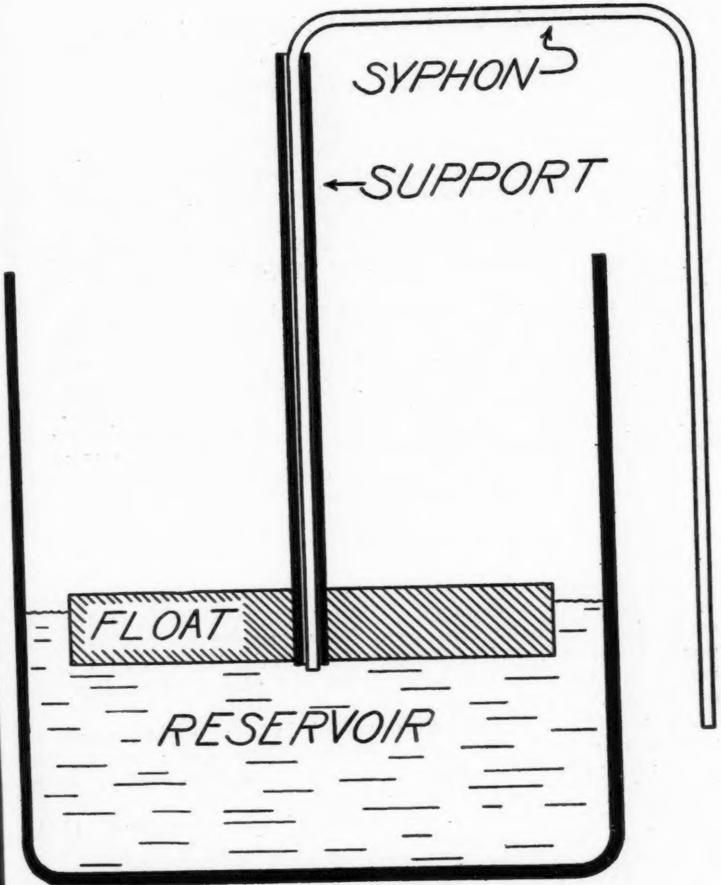

FIGURE 1

Diagrammatic sketch showing the details of construction and assembly of the constant flow syphon for use in prolonged dipping of trout.

PRODUCTION OF LARGEMOUTH BASS

CHARLES O. HAYFORD
State Fish Hatchery, Hackettstown, N. J.

As stated in previous transactions of the American Fisheries Society we have been continually experimenting in the propagation of large quantities of giant daphnia, known as the *Daphnia magna.* We are now able to produce this daphnia in any quantity desired either in our small concrete pools 5 x 30 holding approximately 300 cubic feet of water or in the rearing ponds ½ to 1 acre in extent.

Until this year we transferred the bass fry direct from the reservoirs and breeding ponds to the rearing ponds. By this method in the year 1930-31 the average yield per acre was 8,810; in the year 1931-32 the average yield was 9,992; in the year 1932-33 the average yield was 13,978; this year the yield was 27,519.

This year's bass fry were very uneven in size and some lots were much stronger than others. We realized there would be a severe loss in cannibalism unless the bass were properly graded, therefore, as fast as these fry were collected they were graded through a fine wire sorter and placed in concrete nursery pools, fed by a small pipe of water ranging in temperature from 65 to 75 degrees.

One of the hatchery attendants worked constantly over these bass feeding them daphnia. To our surprise, in from three to seven days the baby bass were following him up and down the ponds like trout. After the bass had attained a size of 1 to 1½ inches in length they were regraded and placed in rearing ponds containing ¼ to 1¼ acres.

As soon as the bass were placed in the rearing ponds the attendant immediately started feeding them finely ground fillet of herring and sheep hearts. In 6 to 8 weeks time the bass ranged in size from 2½ to 5 inches in length.

Nine ponds containing 4.51 acres of water produced 124,115 bass of the following sizes:

98,475	2½	to	3	inches
20,320	3	to	4	"
5,320	4	to	5	"

This work will be rechecked for the purpose of further eliminating loss by cannibalism. I believe this is a better method and is much cheaper than the method we formerly used of drawing the ponds and grading the bass when they were 6 to 8 weeks old. One thing sure, with this system we retain all the natural food in the pond.

1933 PRODUCTION OF LARGEMOUTH BASS, STATE FISH HATCHERY, HACKETTSTOWN, N. J.

Pond No.	Acreage	No. 3	No. 4	No. 5	Totals	Average per acre
No. 1	.23	3,450	1,425	160	5,035	21,891
No. 2	.25	5,400	1,200	280	6,880	27,520
No. 3	.28	1,500	900	280	2,680	9,575
No. 7 E. H.	.47	15,300	1,320	40	16,660	34,446
No. 8 E. H.	.75	31,575	1,200	940	33,715	44,953
No. 13	.92	28,650	3,000	2,500	34,150	37,119
No. 11	.65	4,650	4,725	440	9,815	15,100
No. 150	.21	3,750	975	200	4,925	23,452
No. 15	.75	4,200	5,575	480	10,255	13,675
	4.51	98,475	20,320	5,320	124,115	

Average yield per acre—27,519.

Discussion

MR. EARLE: Can you tell me the average cost of the sheep's heart?

MR. HAYFORD: We buy the sheep's plucks. Of course we use tremendous quantities in our food for trout, and we cut the hearts right off the plucks. The average contract price at the present time for 200 tons is $4.07 per hundred. But the fillet of herring is the best food—salt water herring—we get that direct from the coast. It is perfectly fresh, and ground very fine. These little bass take the food very readily, and that is the reason we can raise such large quantities, because it is just a question of feeding them. I do not see any reason why you should not raise a lot of bass as well as a lot of trout.

MR. FOLLETT: Do you separate the bone from the herring?

MR. HAYFORD: Yes, we use nothing but the fine meat. We take the skin right off—cut the clear meat right off with a sharp knife. There is no bone in it.

MR. WEBSTER: What method do you use in sorting one and one-half inch bass?

MR. HAYFORD: We use screens of the mesh that lets them through—four to six meshes to the inch, I would say. You have to get a wire mesh of the size above what you are letting through. It is a square mesh wire. We often have to use three or four grades of wire to get them through as we want them, in the different sizes.

MR. FOLLETT: Isn't that herring flesh good trout food?

MR. HAYFORD: Yes, we use large quantities of it—about 150 tons a year.

MR. LECOMPTE: You refer to the raw meat of the herring, do you?

MR. HAYFORD: Yes, raw meat—everything is raw.

MR. LECOMPTE: Do you use the canned herring?

MR. HAYFORD: We have used canned herring put up by the Bolto people, and they take that readily after the natural food, but they will not start on the Bolto as they will on the fresh herring, freshly frozen and kept in the best condition until we give it to them.

MR. LECOMPTE: The results with the cooked herring were as good as with the raw meat, were they?

MR. HAYFORD: I wouldn't say they were as good or not as good, because we did not start from the beginning; in order to determine that you would

have to run a check through from the start. But I do know that they readily eat the Bolto after they are two or three inches long.

MR. LECOMPTE: That is what I wanted to know—whether you carried on an experiment in one pond with raw meat and in another pond with the cooked meat.

MR. HAYFORD: No.

MR. FOLLETT: I think I was misunderstood with regard to the raising of adult lake trout and salmon in captivity. My friend here says the fish he had were placed in the ponds when they were fingerlings; these fish I refer to were fish weighing twenty or thirty pounds; they had been taken in the wild state and placed in this pond simply as show fish, and they said they had never reproduced. I have had some experience with salmon taken in the wild state.

THE NUTRITIONAL REQUIREMENTS OF BROOK TROUT*

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AND
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During the past year we have resumed our nutritional studies of trout at the Cortland Hatchery. The hatchery, formerly used for the propagation of trout, was remodeled to fit the requirements for carrying on nutritional research (1).

The technique employed in these studies is very similar to that used in our work at the Connecticut State Hatchery at Burlington (2). The work at that hatchery was carried on for about five years and the technique used proved to be satisfactory. The water supply for the Cortland hatchery has a constant temperature of 47±0.5 degrees F. throughout the year. Although the fish make slower growth at this rather low temperature this disadvantage is more than offset by the fact that we have one more variable under control.

In our practical experiments the aim is to develop a diet which will produce good growth and strong, healthy fish and be inexpensive as compared to the usual hatchery diet of raw meat.

The aim of our basic studies is to determine the actual fundamental nutritional requirements of trout, in terms of carbohydrates, fats, proteins, minerals and vitamins. These results can then be applied to the practical side of the nutrition of trout.

A large reduction can be made in the feed costs of hatcheries by partial substitution in the meat diets of such dry feeds as dried skimmilk, dried buttermilk, cottonseed meal, peanut meal, fish meal, meat meal and cereal by-products. For the past several years, another dry feed, salmon egg meal, has been recommended by Davis (3) as a partial substitute for a meat diet. Of the many dry feeds tested, we know of only one which has proven toxic to trout, linseed meal (4) (5).

In previous experiments (6) we found beef liver to be somewhat superior to the other hatchery meats. In order to further test the qualities of the different meats employed in hatcheries we have set up three meat variables in Diets 1-4. Diets 1 and 2 also have a variable of skimmilk vs. buttermilk. The complete composition of the diets is shown in Table I and the growth curves of the various groups are presented in Chart I. The growth curves indicate that there is very little difference in sheep liver, sheep hearts, or beef spleen when used in combination with such dry feeds as dried skimmilk and cottonseed meal. Somewhat better growth was made with the skimmilk than with the buttermilk.

*These studies have been made possible through the cooperation of the New York State Conservation Department, The U. S. Bureau of Fisheries and Cornell University.

TABLE I*

Diet No.	Sheep Liver[1]	Sheep Heart	Beef Spleen	Dried Buttermilk	Dried Skimmilk[2]	Cottonseed Meal
1	33	—	—	—	33	34
2	33	—	—	33	—	34
3	—	33	—	—	33	34
4	—	—	33	—	33	34

*Composition of diets is given in per cent by weight.
[1]Sheep liver was fed until February 8th after which date beef liver was employed.
[2]Skimmilk No. 1 was used until December 14th after which date skimmilk No. 2 was employed, see notes on the various skimmilks in Table II.

In addition to securing data upon the hatchery meats we desired to determine the effect of the method of manufacture upon the nutritive value of skimmilk. Experiments designed to show the nutritive value of dried buttermilk, cottonseed meal and peanut meal were also included. Table II gives the composition of the various diets. Diet 11 serves as the meat control. The growth curves of the fish fed these diets are shown in the Chart 2.

The growth curves of the fish on Diets 5-8 indicate that there is little or no difference in the nutritive value of the four skimmilks manufactured by different methods. The spray process skimmilk is the best binder of other dry feeds used in trout diets. The dried buttermilk, Diet 9, proved slightly inferior to the skimmilk and slightly better than the sheep plucks when it was substituted for half of the meat, Diets 11 and 12. These differences are not significant statistically.

TABLE II*

Diet No.	Sheep Plucks	Cottonseed Meal	Peanut Meal	Dried Buttermilk[1]	Dried Skimmilk[2] No. 1	No. 2	No. 3	No. 4
5	33	34	—	—	33	—	—	—
6	33	34	—	—	—	33	—	—
7	33	34	—	—	—	—	33	—
8	33	34	—	—	—	—	—	33
9	33	34	—	33	—	—	—	—
10	33	—	34	—	—	33	—	—
11	100	—	—	—	—	—	—	—
12	50	—	—	50	—	—	—	—

*The dried milks were secured through the courtesy of the American Dry Milk Institute, Chicago, Ill. The cottonseed meal was furnished through the courtesy of the Chickasha Cotton Oil Company, Chickasha, Oklahoma. The peanut meal and meat scrap (Table 3) was furnished through the courtesy of Darling and Company, Buffalo, N. Y.
[1]The dried buttermilk was manufactured by the Collis Products Co.
[2]Skimmilk No. 1 was Borden's Skimiflakes. Skimmilk No. 2 was the Dairymen's League Spray Process Skimmilk. Skimmilk No. 3 was the Dairymen's League Roller Process (ground). Skimmilk No. 4 was the Dairymen's League Roller Process (flake).

Dried skimmilk can be used in almost every hatchery to advantage. It is one of the best dry feeds to use in the propagation of trout. The average dried skimmilk has the following analysis (7):

Water	3.9%	**Fat**	1.7%
Protein	35.4%	**Lactose**	48.7%
Ash	8.1%		

Since protein is the expensive item in any diet, it is worth remembering that hatchery meats vary in protein content from 14.8% to 23.1% (8) (9). Although we have shown that a level of protein of from 14 to 18% is sufficient to produce good growth, (6) it would be well to bear in mind that another protein, especially the high quality protein found in dried skimmilk, may improve the quality of the meat protein in the trout diet and makes a more complete chemical food for growing purposes. Another quality of the dried milks is their high ash content, rich in calcium. Hatchery meats are low in calcium and it is possible that fish get insufficient of this mineral in their food to enable them to build strong bone structures. Although fish may absorb calcium from water a good supply of it in their diet is a safe guard against weakboned fish. Since trout need little or no fat, the low fat content in skimmilk is a favorable quality. Considering the chemical nature of dried skimmilk, as a whole, one can readily see why it may be recommended as one of the best dry feeds for trout.

Peanut meal and cottonseed meal are about equal in nutritive value in such combinations as Diets 6 and 10 and both are cheap, high protein concentrates, very adaptable to trout feeding.

The fish on Diets 5 to 12 were moved to another water supply, during the first week of December, where the water temperature was much lower and retarded the growth thereafter.

The next groups of experiments were carried on in small troughs with about fifty fish to an experiment.

This year our work with factor H was confined to two feeds, dried meat scrap and dried buttermilk. In order to test these feeds for factor H the Diets 13, 14 and 15 were designed, Table III. The fish on the diets with no fresh meat failed in eighteen weeks. The control, Diet 13, which contained fresh meat used in the test of the dried meat scrap grew well with practically no mortality as the curves in Chart 3 show. We have shown previously (5) that animal waste from slaughter houses are lacking in factor H when they are dried at high temperatures in the presence of air, and the present work with meat scrap supports these earlier studies.

In a previous report (10) dried buttermilk failed in about twenty weeks due to a lack of factor H and in the present study this work was confirmed, as is shown in Diet 15 of Table III and the accompanying growth and mortality curves.

Since we had the two groups of fish from Diets 14 and 15 broken down from lack of H we tested two other products, liver preserved with calcium hypochlorite, commonly known as chlorinated lime, and liver dried in vacuum, in the presence of carbon dioxide and at a temperature of 80 degrees C. These two products were fed with dried skimmilk to the two groups of fish and as the growth

and mortality curves indicate, checked the mortality of the two groups and growth was resumed. These two new groups were called Diets 14A and 15A and were fed for 22 weeks in the case of 14A and 30 weeks for the other group.

TABLE III

Diet No.	Beef Spleen	Meat Scrap	Peanut Meal	Dried Buttermilk	Vacuum Dried Liver	Dried Skimmilk	Hypochlorite Preserved Liver
13	34	33	33	(Canary dextrin used as a binder)			
14	—	50	50	(Canary dextrin used as a binder)			
14A	—	—	—	—	—	80	20
15	—	—	—	100	—	—	—
15A	—	—	—	—	5	95	—

In many field stations, as well as hatcheries, it would prove convenient and economical if meat were fed at intervals of several days and some other less perishable feed used the remainder of the time. In order to test the suitability of such a practice we have designed Diets 16, 17 and 18 of Table IV. The raw meat supplement fed in Diets 17 and 18 at weekly and bi-weekly intervals was equivalent in amount to that received by the fish on Diet 16 for the respective intervals. The curves (Charts 3 and 4) of the three groups show that all three methods gave practically the same results. Diets 17 and 18 show possibilities of being very useful practical diets since there would be a saving of labor in hauling and grinding meat, refrigeration and feed costs. We understand that this method of feeding is used in some hatcheries at the present time.

Brook trout fed entirely on beef spleen over a period of 36 weeks showed no pathological conditions during that time. It is claimed by some that pig spleen produces a cataract of the eye. Since spleen is one of the cheaper hatchery meats and compares favorably with sheep liver and heart as well as the other hatchery meats (6) in a dry feed-meat mixture, any experiments showing that spleen will produce a cataract of the eye will be watched with interest.

It is customary to associate rainbow and brown trout with the warmer trout waters and brook trout with the streams having a somewhat lower temperature. We have designed Diets 20, 21 and 22 to determine the rates of growth of the three species in our hatchery water which has a rather low temperature, being constant the year around, at 47 degrees F. The composition of the diets is given in Table IV. The growth curves (Chart 4) show that the three species made practically the same rate of growth over a 48 week period. However, these fish were of different weights and ages when started and it was thought best to start new groups beginning with the fry. This year we started groups

of the three above mentioned species and in addition one group of lake trout. The results of these experiments will be reported later.

TABLE IV

Diet No.	Sheep Plucks[1]	Beef Spleen	Cotton Seed Meal	Dried Skimmilk No. 1	Skimmilk No. 2	Crisco	Wesson Oil	Fish Meal[2]
16	14	—	29	—	29	—	—	28
17	—	—	34	—	33	—	—	33
(meat supplement fed once a week)								
18	—	—	34	—	33	—	—	33
(meat supplement fed once every two weeks)								
19	—	100	—	—	—	—	—	—
20	33	—	34	—	33	—	—	—
21	33	—	34	—	33	—	—	—
22	33	—	34	—	33	—	—	—
26	25	—	25	25	—	—	25	—
27	25	—	25	25	—	25	—	—
26-27A	33	—	34	25	—	—	—	—

[1]Sheep Plucks were fed until February 8th after which date beef liver was employed.
[2]The fish meal used was manufactured by the Dehydrating Process Co., of Boston, Mass., and is a white fish meal.

In a recent report (1) the question of whether or not a fish could digest fats was discussed. In view of the fact that in the case of man almost all of the low melting point fats, such as butter and lard, are absorbed and very little of the high melting point fats, such as tristearin, are utilized, it seemed very doubtful if trout, a cold blooded animal having a body temperature of about 47 degrees F. in our water, could absorb any of the high melting point fats and probably only a small amount, if any at all, of the more common low melting point fats. In order to test this, two diets, Nos. 26 and 27, Table IV, were designed. Both diets had the same basic constituents, meat, cottonseed meal, and skimmilk, and to this was added in the case of Diet 26, wesson oil, a low melting point fat. Crisco, also a cottonseed oil which undergoes hydrogenation converting it to a high melting point fat, was added to the basic diet for No. 27. At the end of 32 weeks both groups of fish had made the same rate of growth, indicating that either both of the fats were absorbed or that neither were utilized at all. We endeavored to test this by making a third group and feeding them the basic diet without the fat supplement. One-third of each of the groups, Nos. 26 and 27, were pooled to form this new group, No. 26-27A, and were fed three-fourths as much feed, since there was no fat in the diet and since the fat content of the other diets was 25%. As the curves (Chart 5) indicate this new group made the same rate of growth as those fish receiving the fat supplements. This leads us to believe that neither such high or low melting point fats as crisco and wesson oil are utilized by trout but are excreted as undigested food. Earlier experiments (11) have shown that fish are able to do this without any great detrimental effect on growth. However, this important question of fat absorption by fish needs further experimentation before definite conclusions can be reached.

Last winter about 8,000 black. spotted trout, averaging 3-4 inches in length, suffered a heavy infestation of Octomitus salmonis which resulted in a high mortality. Since we knew of no control measures other than sanitation and since the opportunity presented itself we divided the remaining fish into eight groups and fed them small amounts of various intestinal antiseptics in the hope that we might find something that would rid the fish of the parasite. We fed the antiseptics in small amounts of liver. Table V. shows the dosage used. The fish were examined for the free moving forms of Octomitus eighteen hours after the first

TABLE V

Group No.	Antiseptic	Dosage (in per cent of feed)
1	Mercurous Chloride (calomel)	0.2%
2	Hexamethylenamine	.5
3	Carbon tetrachloride	.2
4	Naphthol (beta)	.5
5	Creosote	.5
6	Resorcinol	Toxic at 0.5%, used at 0.1% with no toxic effects
7	Salol	.5
8	Sodium sulphorcarbolate	.5

feed of the antiseptics. Three groups, those receiving the mercurous chloride, carbon tetrachloride and naphthol, showed only a few moving forms. The other groups still showed a heavy infestation. Five days later the fish were again examined and no parasites were found in groups 1, 2 and 4, and only a few in group 3. A week later the fish were again examined and found as just stated. Three groups, not mentioned in the table, were fed 5% chlorinated liver, 3% formaldehyde in the liver and the other was fed 100% buttermilk but none of these had any noticeable effect on controlling the parasite. We realize that this is only a small amount of evidence for the control of an intestinal parasite but offer it in the hope that those persons interested in the field of infectious disease can make some use of such preliminary work. We believe that we have destroyed the parasite at one stage but know nothing of the other phases of its life history. Whether or not the antiseptic can be safely used at higher dosages we do not know. However, it is probable that either mercurous chloride or naphthol can be fed at fairly high levels with no toxic effects.

SUMMARY

Our experiments this year show that:

1. Brook trout will make good growth on diets composed of two-thirds dry feed and one-third meat when the dry feed used is such products as dried skimmilk, dried buttermilk, cottonseed meal and peanut meal mixed in various combinations.

2. Sheep liver, sheep hearts and beef spleen compared favorably with each other when fed in dry feed-meat mixtures.

3. Brook trout will make good growth when fed dry feed mixtures with meat supplements given at intervals of one or two weeks.

4. It is probable that neither high nor low melting point fats are utilized by trout.

In conclusion we wish to thank Dr. G. C. Embody, who is cooperating with us in our work with the intestinal parasite, Octomitus Salmonis.

BIBLIOGRAPHY

1. McCay, C. M., Report of the Experimental Work at the Cortland Hatchery, For the year ending December 31, 1932. New York State Conservation Department.
2. McCay, C. M. et al. Trans. Amer. Fish. Soc. (1927) 57.
3. Davis, H. S., and Lord, R. F., Memorandum, Dept. Comm., Bur. Fish. Washington, D. C. 1932.
4. Almy, L. H., and Robinson, R. K., Jour. Biol. Chem. (1920) 43, 97.
5. Titcomb, J. W., et al. Trans. Amer. Fish. Soc. (1929) 59.
6. McCay, C. M., et al. Trans. Amer. Fish. Soc. (1931) 61.
7. Rogers, L. A., and Associates, Fundamentals of Dairy Science (1928), p. 34
8. Embody, G. C., and Gordon, Myron. Trans. Amer. Fish. Soc. (1924) 54.
9. Sherman, H. C., Chemistry of Foods and Nutrition.
10. Titcomb, J. W., et al. Trans. Amer. Fish. Soc. (1928) 58.
11. McCay, C. M., et al. Trans. Amer. Fish. Soc. (1930) 60.

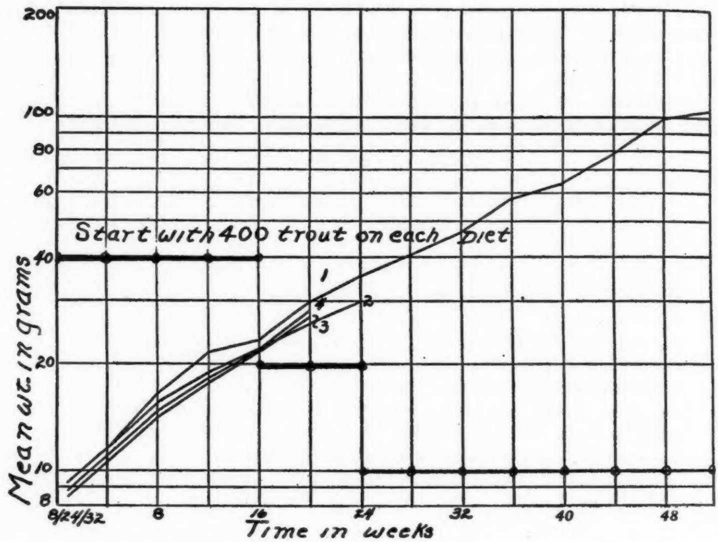

CHART 1.—Curves 1-4 show that very little difference in growth is caused by various hatchery meats in a dry feed-meat diet. Sheep liver was fed in Diets 1 and 2, sheep hearts in Diet 3 and beef spleen in Diet 4.

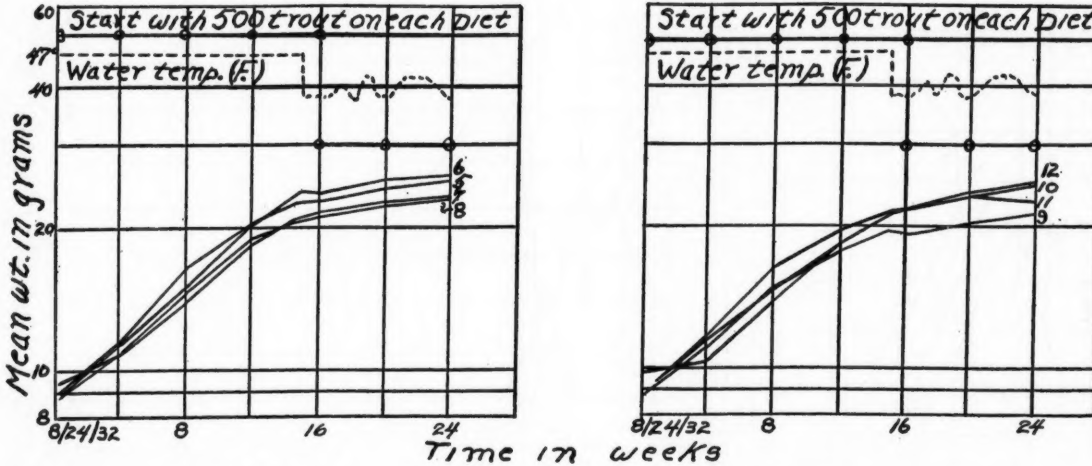

CHART 2.—Curves 5-8 show that dried skimmilk manufactured in four different ways still has about the same nutritive value. Curve 9 compares buttermilk with the skimmilks. Cottonseed and peanut meal are about equal in nutritive value, contrast curves 6 and 10. Curve 11 shows the growth rate of trout fed sheep plucks. Curve 12 shows that buttermilk can be substituted for half of the sheep plucks.

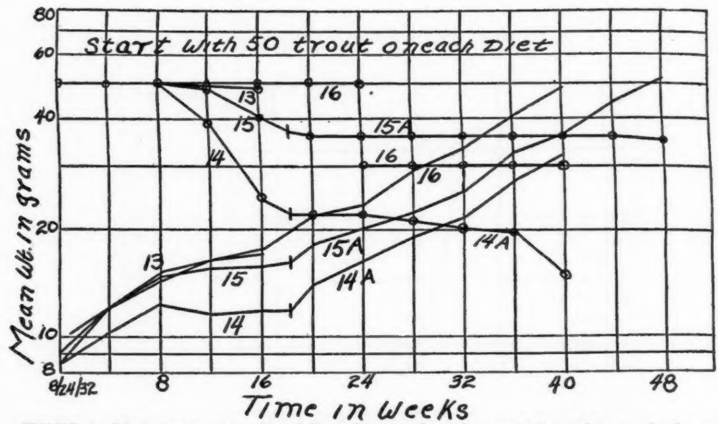

CHART 3.—Meat scraps caused a failure in growth and a mortality when no fresh meat was added, contrast curves 13 and 14. Liver treated with calcium hypochlorite revived the fish, curve 14A. Buttermilk caused a failure in growth and a mortality when fed exclusively, curve 15. Vacuum dried liver revived the fish in this case, curve 15A.

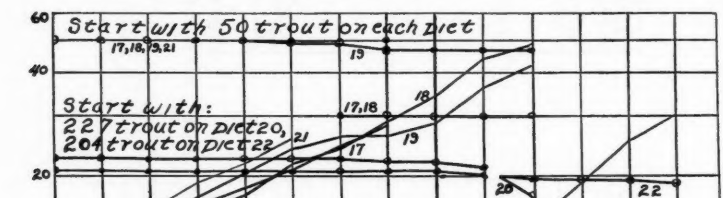

CHART 4.—The meat supplement can be fed either daily, weekly or bi-weekly with practically the same results, contrast curves 16 (Chart 3), 17 and 18. Curve 19 shows the growth and mortality of trout on a beef spleen diet. Three species of trout, rainbow, brook, and brown, fed the same diet, made practically the same rate of growth, see curves 20, 21, and 22.

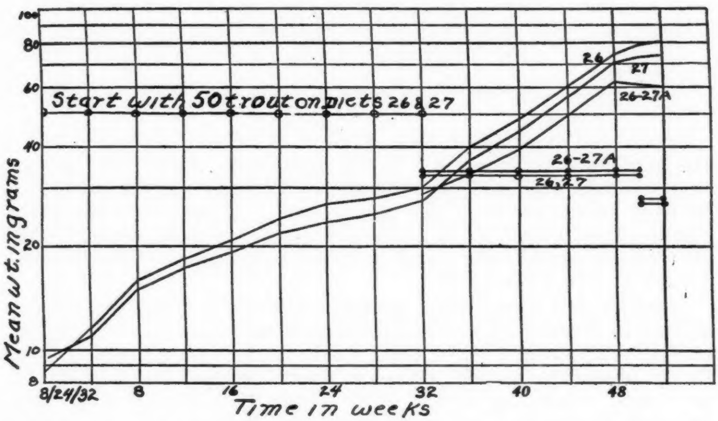

CHART 5.—Curves 26-27 and 26-27A show that trout utilize little or no fat, either of high or low melting point.

MAYFLIES—A STAPLE FOOD OF FISHES IN HILL STREAMS

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In the hill streams of New York it is the brook trout that is the angler's chief interest. Brook trout have foods that are not of the kinds used in the hatcheries. Perhaps insects never will be used there, yet they are staple foods. I speak of the herbivorous insects that grow naturally in the brook, among which are mayflies, caddis flies, and midges. It is the mayflies to which I wish to direct attention.

Mayflies are found only at the waterside. They are delicate insects that one often sees fluttering singly from the water surface up to the tree tops, or that sometimes gather in great swarms. Every observant angler has seen them snapped up by fishes at the water when they settle down close to it to lay their eggs. As adult insects they are very short lived, at most only a few days being allowed them, but as larvae in the water they live long. Most of them require a year for development, and some of them several years. It is as larvae that most of them are eaten, and this of course is not observed by the angler: what goes on under the water is really far more important than what is seen at the surface. Mayfly larvae are available and are eaten by fishes all the year around. Stomach examinations of small stream fishes everywhere have shown a high percentage of mayfly larvae in the food. I have found in the Wasatch Mountains of northern Utah more than fifty per cent of the food of rainbow trout to be mayfly larvae of the genus Ephemerella.

These larvae live mainly under stones in the riffles. They become dislodged with the rolling of the stones, and they drift with the current into the pools where the trout lie in wait. When grown they crawl or swim to the surface to transform. Often they are not successful, but are caught in the current and swept down stream. Drift-net studies by Paul R. Needham have shown that a large proportion of the fish food carried by the current is mayflies.

Mayflies are very prolific. A single female of any of the larger species may lay several thousand eggs. If only a very few adults escape being eaten they may supply eggs enough to restock the stream.

The food of mayfly larvae is mainly plants of a lowly sort—the algae that grow upon the rocks in the riffles. These are very minute plants—most of them microscopic; but they make up in numbers and reproductive capacity what they lack in size. Some

of them are diatoms and live in the film of ooze that covers the submerged stones, making them brown and slippery. Others are green algae that form fringes trailing in the current from the downstream side of the stones. These thrive best in sunny riffles, which are the "meadows"—the chief food-producing area of fish forage. The pools below them where the trout lie are the "feed lots."

In most of our clean streams, where plant life has not been destroyed by pollution, there is much more forage grown than is utilized. That is to say, our streams are capable of producing more mayfly larvae and other herbivorous aquatic insects than they yield at present. More of fish-sustaining forage might be raised in them. Stocking is needed, not at first with more fishes but with more food animals to insure a living for the fishes that are there.

Our culture of fishes began with saving the eggs. I call your attention to the fact that the culture of mayflies has in England begun with saving the eggs. There, it has been found that the eggs laid on projecting stones are greedily devoured by many kinds of enemies. When a float is anchored above the surface and attached with wire to the bottom so that it does not get away, eggs are then deposited on the float and the enemies cannot crawl up the wire to get at them, with the result that vast numbers of them hatch which would otherwise be eaten. This is a very crude beginning to be sure, but one that has undoubtedly increased in certain streams the number of available mayfly larvae.

Fishes must eat; food is the first requisite of all living things, and the food that will be available in the streams that we love to visit will have to be produced in those places. There is excess of eggs naturally produced, and some of it can be saved by protective measures. We have not in this country as yet done anything in that line; we are lacking in the necessary information.

The way to find out is to live with these useful species, just as we have done with the species of economic importance in agriculture: cut the problems small enough so that they can be handled; put on each job someone with time and training and equipment, and let him alone; do not ask for results prematurely.

All economic procedure is based ultimately on the intimate and detailed knowledge of habits and natural history. We have never gotten down to careful and sustained observations in this field. We have not really made a start in the control of the life of this rapid, clear water of our hills.

If we could do for the extraordinarily fecund mayflies anything comparable to what we have done for the fishes by means of hatcheries, you can readily see what an increase of fish food would result. Here is where our aquiculture lags. The game fishes themselves, have not received too much attention, but their for-

age has received far too little. We are only beginning to study the smaller "bait" fishes, with a view to controlling the supply. We have done almost nothing to increase production of the staples of food for small fishes. It is here that aquiculture has fallen farthest behind agriculture. The insects that affect land crops in North America are looked after by several hundred well trained and well paid entomologists. Those that affect our fish crop—even those that most sustain it in inland waters—are neglected altogether. There is not a single person paid to devote his time to their study. A few persons give to it such time as they can steal from other occupations. I believe that increase in fish forage in our hill streams will come when properly equipped persons have been assigned to definite and specific tasks and kept at them long enough to find out something. As in agriculture so here the old complemental methods of observation and experiment will bring the increase.

Discussion

Mr. Adams: I would like to ask Dr. Needham whether the success of that Mayfly culture would be dependent on stream management that would guarantee more or less a constant volume of water in the stream? Would there not be a great mortality through the rise and fall of the level of the streams that is characteristic of most streams in this country?

Dr. Needham: Undoubtedly there are casualties in the streams that we shall never be able to control, but under natural conditions there are enough in there to keep things going, and there is no reason why we cannot increase the amount by the same methods as those employed with fishes, if we could only find out how to carry these animals past the point where the greatest losses occur.

Mr. Adams: In some of our streams the natural reproduction of trout is more or less a thing of the past. Where fish large enough to be caught are put into those streams, how would you go about making an intensive production of Mayflies or any other food that would to some extent match this intensive stocking?

Dr. Needham: I confess I do not know; I am only standing up here and telling you I believe I know the way to find out. But it has not been tried.

Mr. Wickliff: How long do the legal trout put in these streams stay there? What percentage do the fishermen catch before they have had a chance to eat very much?

Dr. Needham: Do not ask me such difficult questions—I do not know.

Mr. Wickliff: Mr. Adams raised a point, and I would like to know what percentage of legal trout they put in these streams that the fishermen catch are caught out before the food supply is exhausted. Perhaps somebody from New Jersey could give us some information on that.

Dr. Needham: I cannot even attempt to answer the question.

Mr. Adams: I think we all recognize in Dr. Needham a pioneer in the work in this particular field. In the early days of the development of the arti-

ficial propagation of game birds we felt that the maggot was a very necessary element in the feeding of game birds, and we still think so—if it were possible to produce maggots on an enormous scale, at a price. Dr. Needham, through his pioneer work in that field, evolved a plan for producing maggots without animal food but on vegetable products, and he is running true to form in bringing forward now the same line of thought in regard to the animal life required in our streams for the feeding of our fish. I only hope that in the several states as time goes on, the men who have charge of this work will emphasize the fact that Dr. Needham and his group are certainly working in the right direction. It is a good deal like what Charlie Hayford said to me yesterday—as a matter of fact we are producing today in the several states the volume of fish that we actually need for restocking purposes, were it a fact that we could mesh our fish production with the scientific research that Dr. Needham suggests and get into those streams a proper food supply and bring about a condition under which all the favorable biological factors are present to match the artificially produced plantings that we made in those streams. I hope that we will give increasing attention to this matter of scientific research rather than proceeding alone on the practical side of the work of striving to produce more and more fish and shoving them into our waters with very little thought as to what they will find in the way of food and cover and living conditions after they are chucked in there.

Dr. Needham: Just one word more. I work in the agricultural experiment station. The insects affecting agriculture are attended to by at least five hundred men paid for the job, while in aquiculture, in our fish raising, we have not one man paid anything to deal with the important question of insects as fish forage.

The President: Can you answer the question Mr. Wickliff put, Mr. Hayford?

Mr. Hayford: Would you repeat the question, Mr. Wickliff?

Mr. Wickliff: I understand you introduce legal trout into your streams and allow the fishermen to go out and catch them soon after they are introduced. The question is, how long do these legal trout remain in the streams before the fishermen are allowed to go out and catch them?

Mr. Hayford: That is rather a hard question to answer, because the conditions in the stream might be good and they might catch a great many more than they would under other conditions which would not be so good. I think there ought to be further study on that question. It is a matter of intelligent planting with reference to food conditions in all the streams.

The President: Is there any further discussion on this important presentation made by Dr. Needham? The importance of increasing fish food production in our streams can hardly be overemphasized; it is one of the great problems that is facing us at the present time. It is unquestionably true that in many cases several times the number of fish are being planted in our waters that these waters under present conditions can support. The problem is one which I think will be a major question we shall have to meet in the near future.

TYPE OF FOOD TAKEN THROUGHOUT THE YEAR BY BROOK TROUT IN A SINGLE VERMONT STREAM WITH SPECIAL REFERENCE TO WINTER FEEDING

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Within the last six years many instructive papers referring to the food of wild trout have been presented before this Society. I will not attempt a review of these papers here, but have referred to them in the bibliography. With few exceptions, notably Needham (1930), the authors have considered particularly the food of trout taken during the warmer months, and have given a fairly complete picture of the kind of organisms usually eaten by trout of various species at the time when food is most abundant. Needham went a step further and included data secured during the winter months, but his collections were meager and incomplete.

The present paper is the result of an investigation intended originally to throw light on the winter feeding habits of brook trout, by means of systematic collections of trout stomachs at weekly intervals during the cold weather. As time went on it appeared more and more desirable to continue the sampling throughout the entire year, and thus secure a more complete picture of the seasonal food. It should be emphasized however, that the present paper is not an attempt to describe seasonal trout food in general. The data presented are merely intended to describe the forage available in a certain section of one stream throughout an entire year; to show how the character of the trout food changed as the warmth of summer gave way to the bleakness of the northern winter. The results are thus only applicable to this one stream, or to other brooks of the same type, although the observations do blend nicely in the accepted picture of what constitutes trout food in general.

THE BROOK

Before such a program could be undertaken it was necessary to find a trout stream suitable for year-round collections. The brook finally selected represented the headwaters of a small stream which was five or six miles in length, but never over fifteen feet in width at the largest pools. Brook trout were extremely abundant.

The part chosen for systematic seining was very narrow, some portions of it being completely hidden by the bending meadow grass in summer and by drifted snow in winter. It flowed through open meadow land. Although aquatic plants were absent, the

banks were undermined throughout the entire section, thus affording a wealth of hiding places for the fish. A great abundance of low-growing willows, alders and lesser bushes also offered additional protection.

The narrow width made it possible to place a small seine entirely across the current and to drive the trout into it by wading down stream, making as much commotion as possible in the process.

Much more to the point, the stream in question was one of the few nearby brooks which did not become so icebound in winter as to make collecting virtually impossible. The lowest water temperature was 35 degrees F. on January 30, 1932. On the same date a year previous the temperature was 38 degrees F. At this time the snowfall was exceptionally heavy, so that through January, February, and up to the end of March the brook was virtually buried under a covering of snow which protected the water from extremely cold weather. The snow was no doubt responsible for a remarkably constant water temperature of 38 degrees F. which was prevalent during the months mentioned in 1931. In April the water began to warm up, the maximum reading of 63 degrees F. being secured on the first of August.

It is probably owing to the favorable water temperature during the winter that the trout actually did more feeding than they would have in a brook where the water nearly reached the freezing point. In fact, trout from the stream in question have always been fat and plump, even early in spring, while those from a larger nearby stream in which the water frequently reaches 33 degrees F. during the winter, are nearly always very thin at the start of May fishing despite the great abundance of food in the brook itself.

Method of Taking Trout Samples

Although angling methods have been used to secure most of the trout stomachs examined by other investigators, it was thought that a more accurate conception of trout food would be gained if the fish were all taken with a seine. Previous observations have shown that trout tend to concentrate on different types of food under different feeding conditions, with the result that stomachs of fish taken under only one condition would give a misleading idea of the food in general. That is, fish caught by a fly-fisherman at a time when a mayfly "hatch" was on, would give an entirely different impression of trout food than would be revealed by an examination of stomachs from fish caught on bait at a time when the stream was filled with roily water and the fish were busy concentrating on the spoils washed from undermined banks or beds of a silt and leaf-drift.

Seining does not limit itself to surface-feeding or bottom-feeding fish, but results in a more representative sampling of the available trout population, catching feeding and non-feeding fish without discrimination. With seining as the preferred method it was decided to take approximately ten trout per week and on the same days of each week if it was at all possible.

This schedule was adhered to very closely. It must be admitted that the type of seining done on a blustery winter day when the net froze stiff the instant it was lifted from the water, and the netters wallowed through snowdrifts that reached the tops of fence posts, left much to be desired.

Method of Stomach Analysis

One method of analysis consists in enumerating each kind of organism, and then computing the percentage of each item based on the numbers found. Needham used this method also to show the selectivity of the trout in feeding. Another method consists in measuring by some means the bulk of each kind of food and in basing the percentage on volume rather than number. Data secured by both of these procedures help us to understand what constitutes trout food in general, although these and other methods are open to criticism.

The enumeration method, while doubtless showing the food preferences of trout, does not account for the difference in bulk. Midge larvae for example are often very small and a great many are required to furnish the nourishment represented by two or three of the larger caddis worms. On the other hand, direct bulk comparisons, volume for volume, are also unsatisfactory. For example, one trout out of a sample of ten or more fish might contain a relatively rare item such as a salamander, which due to its bulk might constitute fifty to seventy-five percent of the total volume of food in all of the stomachs. It is fairly obvious that a statement to the effect that salamanders make up seventy-five percent of the food eaten by trout is erroneous.

In order to gain a more accurate idea of the composition of trout food, it was decided to use a method, not a new one by any means, that as far as possible would limit the effect of any one individual stomach on the results as a whole. Thus, the following technic was employed.

1. The stomach was taken from a trout and all adhering organs removed. The intestine was snipped off directly behind the stomach, no effort being made to examine the intestinal content because undue emphasis would then be placed on hard-shelled insects such as beetles, or stone-protected larvae such as caddis, while the soft-bodied animals would be in a fragmentary or disintegrated state very difficult to identify. Analysis and comparisons were thus based on the content of the stomach proper.

2. The stomach was cut open with scissors, the contents placed in a small glass dish of water, and then teased apart with dissecting needles under the binocular microscope. The various food items were then classified.

3. A section of graph paper was next inserted under the glass dish, and the various food organism, each according to its kind, were spread in a uniform layer over the necessary areas.

4. The percentage of each type of food was determined by counting the squares covered and the results from each stomach were then tabulated.

5. Finally the percentages of each food in a day's sample were added, and the *average percentage* determined by dividing the totals for each kind of food by the number of fish in the sample. Monthly percentages were determined by a similar treatment of the weekly data.

This method of finding the average percentage of each type of food eliminated the danger of any one fish having undue influence on the total. Even though the contents of one stomach consisted entirely of some very bulky food item, it would not tend to distort the picture. That is, referring once more to the example of the salamander, even though such an unusual item made up the entire 100% of the food in any one fish and also made up a very high percentage of the total volume of food, its effect would be discounted as more and more stomachs came into the picture. The procedure followed puts crammed stomachs and lightly-filled stomachs on an equal basis, and seems superior to the bulk for bulk method as it results in placing an unusual although bulky food item in a more reasonable relationship to trout rations as a whole. It is realized that in dealing with this, and other methods of presenting averages, we are drawing with rather sweeping lines, but even so an effort should be made to keep generalities within the bounds of plausibility and common sense.

Discussion of the Trout Food

What follows is an attempt to show clearly by text, tables and diagrams how the type of food changed as the months passed. In most instances specific identification of various food animals was not attempted, their allocation to the various orders being considered sufficient, except when a certain form was unusually conspicuous in the stomach contents. In the course of the analysis of 550 trout stomachs it is safe to say that practically all of the common genera of typical trout stream insects were observed. There was also an extremely wide assortment of terrestrial insects, besides spiders, millipedes, centipedes, sowbugs, earthworms and the like. A discussion of the food eaten month by month will follow with the emphasis placed on the high-lights of each month.

JANUARY 1931

Aquatic food	98%
Terrestrial food	2%

JANUARY 1932

Aquatic food	87%
Terrestrial food	13%

Dominant Forms by Average %

January 1931

Caddis (larvae, pupae, adults)	31.11%
Midge (larvae, trace of pupae)	17.11%
Stonefly (nymphs)	9.09%
Mayfly (nymphs)	6.96%
Cranefly (larvae)	6.86%
All other food	28.87%
Total	100.00%

Number stomachs: 41.
Average length of fish: 85.4 mms.
Range: 113—62 mms.

January 1932

Caddis (larvae, pupae, adults)	29.07%
Midge (larvae, trace of pupae)	16.96%
Cranefly (larvae)	16.25%
Stonefly (nymphs)	8.81%
Sowbugs (adult crustaceans)	7.56%
All other food (Mayfly nymphs 5.15%)	21.35%
	100.00%

Number stomachs: 44
Av. Length of fish: 110.4 mms.
Range: 163—67 mms.

Collections of trout stomachs began in January 1931 and continued for a year, ending with collections in January 1932. There was thus a double sample for the month of January and it is very interesting to note the great similarity between the same months of the two years. (See above).

There was little food of terrestrial origin in the January 1931 stomachs. The brook lay buried in snow with little possible chance for land forms finding their way into the water. Of the 2% land food most of it consisted of terrestrial sowbugs, which had doubtless been picked up around an old, tumble-down dam, the damp logs of which furnished an ideal home for the animals. A trace of spiders and snowfleas made up the rest of the land food which obviously was of little importance.

In the aquatic food, caddis dominated. The pupae were specimens of *Philopotamus distinctus,* the female pupae of which are wingless. This caddis fly appeared to be particularly active in the winter months, and the presence of many pupae and some adults enabled this order of insects to play a conspicuous part in the trout food. The dominant stonefly in the January 1931 stomachs was *Taeniopteryx,* well-developed nymphs of which were often found. Stoneflies however, were not abundant in the stream. *Baetic* was the dominant mayfly nymph. Midge larvae and cranefly larvae were the most important *Diptera,* midge larvae being second in importance to the caddis. The January 1931 stomachs showed conclusively that during severe weather trout were almost entirely dependent on the food of the stream itself, this consisting mostly of the immature stages of aquatic insects. There was one salamander present in the monthly sample, and a few aquatic worms; other than these, insects dominated the picture.

The stomachs examined a year later in 1932 contained more food of terrestrial origin. This month however, was quite different from that of the previous year, being extremely mild for New

England, with hardly any snow and often hard rains. It was not surprising therefore to find a higher percentage of land forms in the fish. Sowbugs, for example, were quite conspicuous, the average percentage of the crustacean about equaling that of the stonefly nymphs. Millipedes, spiders, an occasional land beetle or caterpillar, and a trace of earthworms made up the rest of the land food.

The aquatic food was practically the same as for the previous January, both in the type of animals eaten and the average percentages. Cranefly larvae however, were more abundant. This was in all probability due to the rains and high water which would tend to wash the larvae from their protecting beds of silt or leaf-drift. It is of interest to note that one salamander had been taken in January 1932, just as had occurred the year before.

FEBRUARY 1931

Aquatic food	**99%**	**Number stomachs: 43**
Terrestrial food	**1%**	**Av. length of fish: 106.9 mms.**
		Range: 175—61 mms.
Total	**100%**	

Dominant Forms by Average %

Caddis (larvae, pupae, adults)	**43.24%**
Mayfly (nymphs)	**15.68%**
Stonefly (nymphs)	**12.76%**
Midge (larvae)	**10.33%**
Aquatic worms	**5.00%**
All other food	**12.99%**
Total Food	**100.00%**

The February picture was practically a duplicate of the January one. Terrestrial forms were negligible, consisting of a trace of earthworms and spiders.

Among the aquatic foods caddis again took first place, due to the same species as mentioned for January. The mayfly *Baetis* was more abundant than in January, eighty-seven individuals being found in one fish. The presence of 5% aquatic worms was due to the fact that a sample of trout was taken near the place where the spring water from a milk house, and sewers from both a farm-house and barn-yard entered the brook. The trout at this place were quick to take advantage of the additional food supply brought about by the fertilization of the stream. They contained many red midge larvae, some rat-tailed maggots, and a few of them were crammed with sludge worms, all organisms indicative of an abundance of organic material on the stream bottom, if not of pollution itself. The effect of the fertilization was not noticeable over fifty yards downstream, and in no places other than within a few feet of the spot did the trout contain any of the organisms

just mentioned. The effect of the inflow of organic waste was thus more helpful to the trout than otherwise as it increased the food supply.

MARCH, 1931

Aquatic food	97%	Number of stomachs: 46
Terrestrial food	3%	Av. Length of fish: 91.2 mms.
	100%	Range: 172—61 mms.

Dominant Forms by Average %

Mayfly (nymphs)	28.55%
Caddis (larvae, pupae, adults)	26.61%
Stonefly (nymphs, adults)	13.30%
Cranefly (larvae)	7.99%
Midge (larvae, pupae)	11.13%
All other food	12.42%
Total	100.00%

Food taken during March was similar to that of January and February except that mayfly nymphs were more abundant, taking first place, with caddis coming second. There were less pupae of *Philopotamus distinctus* present among the caddis eaten and a larger sprinkling of other forms such as *Hydropsyche*. Newly transformed adults of the big stonefly *Taeniopteryx* were also found in the March stomachs. Midge larvae still played their important part as trout food.

The land food increased slightly due to the presence of earthworms, millipedes, sowbugs, snowfleas, and now and then a beetle. On March 27 the brook was high and the spring break-up had begun.

The observations for January, February and March showed clearly that trout are dependent on food of aquatic origin during the winter. A mild season seems to be responsible for more land forms being available, but year after year it is the food produced in the stream itself that sustains the fish during cold weather.

APRIL, 1931

Aquatic food	82%	Number of stomachs: 41
Terrestrial food	18%	Average length of fish: 89.5 mms.
		Range: 188—60 mms.
Total	100%	

Dominant Forms by Average %

Caddis (larvae, pupae, adults)	27.13%
Midge (larvae, pupae)	12.45%
Mayfly (nymphs)	12.45%
Other Misc. Diptera larvae	11.05%
Cranefly (larvae)	9.56%
All other food	27.36%
Total	100.00%

In the month of April the land forms became more abundant, although aquatic insects made up the bulk of the food taken. Caddis again returned to first place with the inevitable midge larvae and mayfly nymphs even for second honors. A greater variety of miscellaneous aquatic diptera larvae were noted, conspicuous among them being the peculiar little larvae of the mothfly (Psychoda) which likes to lurk in the damp moss that clings to the sides of stones. One fish contained nine of these larvae. It would seem that the sudden rising and falling of the water, so typical of the month of April, would make these larvae, whose normal habitat is out of reach, more accessible to an alert trout. Cranefly larvae were also slightly more abundant, and this too was probably because of the flood water.

Beetles were most conspicuous among the terrestrial organisms, with caterpillars next. A sprinkling of ants, bees, sowbugs, spiders and so on made up the rest of the land food. It was very apparent that land organisms were beginning to stir abroad and that the trout were ready to add them to their diet.

MAY, 1931

Aquatic food	73%	Number stomachs: 37
Terrestrial food	27%	Av. length of fish: 94.1 mms.
		Range: 126—63 mms.
Total	100%	

Dominant Forms by Average %

Midge (larvae, pupae)	37.65%
Caddis (larvae, pupae, adults)	12.61%
Earthworms	11.48%
Land Beetles	11.35%
Mayfly (nymphs)	9.27%
All other food	17.64%
Total	100.00%

The May stomach revealed that the trout were finding an increase in the amount of terrestrial food as the weather became milder. Nevertheless, aquatic food was still dominant, with midge larvae and pupae taking first place and caddis second. Considering the effect of weather and stream conditions on the type of feeding done by the trout, it might be well to mention that although midges played an important part in all of the May samples taken, they were more abundant in trout captured on days when the water was low and clear rather than in a state of flood. Any one who has observed trout working over the bottom material in search of midge larvae can realize that low, clear water would be more conducive to this sort of foraging.

When the land food is considered, the presence of earthworms in third position is slightly misleading. After legal fishing opened on May 1 there was frequently some person fishing with worms in the seining section. This probably accounts for the high percentage of worms in the stomachs. Terrestrial beetles for the first time appear in numbers in the stomach contents. It has been noticed that various species of beetles are quite common in trout that have been surface-feeding. As beetles are clumsy, blundering insects for the most part, this is not surprising. It is perhaps significant that there were more beetles in the May 23 sample which was taken on a cold rainy day following a spell of mild weather. Such a change might have so chilled and weakened the beetles that they were less able to keep from falling into the stream.

JUNE, 1931

Aquatic food	48.5%	Number stomachs: 20
Terrestrial	51.5%	Ave. length of fish: 98.1 mms.
		Range: 129—75 mms.
Total	100%	

Dominant Forms by Average %

Caddis (chiefly larvae)	28.30%
Land beetles	12.75%
Misc. land insects	12.35%
Ants	8.55%
Mayfly (nymphs)	12.20%
All other food	25.85%
Total	100.00%

June finds terrestrial forms slightly in the lead, although the aquatic organisms are still important food. Caddis was again very conspicuous. The value of caddis larvae as trout food can scarcely be over-rated. Like the inevitable midge larvae, these insects make up the "bread and butter" of the trout, being nearly always accessible, and, due to their mode of life, easy to catch. Mayfly nymphs, too, rate among the staple trout foods, and it is rare to find a stomach without a trace of these insects.

In general, June marked the beginning of a veritable shower of land insects, with the trout ready to accept anything within reach. The season of plenty had begun, but still, the aquatic forms were far from being ignored. Beetles and red ants were conspicuous enough among the land organisms to be given a separate rating. Miscellaneous flies, bugs, bees, wasps, and so on were lumped in the analysis and made up 12.35% of the total food. Caterpillars, millipedes, spiders and earthworms made up the rest of the land food.

JULY 1932

Aquatic food	60%	Number stomachs: 50
Terrestrial food	40%	Average length of fish: 105 mms.
		Range: 145—81 mms.
Total	100%	

Dominant Forms by Average %

Caddis (larvae chiefly)	32.70%
Mayfly (nymphs)	13.20%
Land beetles	12.38%
Ants	9.01%
Cranefly (larvae)	3.85%
All other food	28.86%
Total	100.00%

A word of explanation is due regarding the July stomachs. It was the original intention to concentrate on winter food studies, starting in January and ending June 30, 1931. The results of the analysis were so interesting however, that it was decided to continue sampling throughout the summer, but unfortunately by the time the decision was made the month of July had passed and it was only possible to take the sample in the following year (1932). It was realized that this would make a break in the series, but at the same time it did not appear that the July food in one year would differ very materially from that of the same month in another year. An examination of the data listed for June 1931 and July 1932 shows that there is a great similarity; in fact, the kind and comparative percentages of the various items are essentially unchanged.

Caddis is again in the lead, and mayfly nymphs, land beetles and ants occur among the five dominant forms. Aquatic food in general, instead of falling off is more abundant in the stomachs for July 1932 than for June 1931, being higher by 11.5%. This is hardly enough to be significant. The July stomachs clearly indicate the great importance of aquatic food even after summer is really under way and land animals are becoming more abundant and accessible.

AUGUST 1931

Aquatic food	39%	Number stomachs: 40
Terrestrial food	61%	Average length of fish: 90.6 mms.
		Range: 133—61 mms.
Total	100%	

Dominant Forms by Average %

Miscellaneous land insects (Chiefly Diptera and Hemiptera)	19.28%
Grasshoppers and crickets	17.91%
Ants	15.85%
Mayfly (nymphs)	15.73%
Midge (larvae)	10.40%
All other food	20.83%
Total	100.00%

In the month of August terrestrial insects were clearly dominant, but mayfly nymphs and midge larvae were still prominent among the more important food items. Red ants, which had been conspicuous in the stomachs since June, were still common. Grasshoppers entered the picture for the first time. Although terrestrial flies and bugs, taken as a unit, dominated the land insects eaten, the grasshoppers ran a close second.

SEPTEMBER 1931

Aquatic food	45%	Number stomachs: 21
Terrestrial food	55%	Average length of fish: 96.5 mms.
		Range: 153—59 mms.
Total	100%	

Dominant Forms by Average %

Grasshoppers and crickets	29.54%
Midge (larvae)	17.77%
Ants	11.93%
Land beetles	11.57%
Caddis (larvae chiefly)	10.95%
All other food	18.24%
Total	100.00%

Terrestrial food was most important in September, with the annual fall crop of grasshoppers playing a leading role. Ants and land beetles were next in abundance.

Midge larvae were the principal aquatics with caddis larvae returning again to an important position.

Although only twenty-one September stomachs were examined, they showed conclusively that the fish fed for the most part on terrestrial organisms, but with the staple aquatics still very much in the picture.

OCTOBER 1931

Aquatic food	38%	Number of stomachs : 41
Terrestrial food	62%	Average length of fish: 117.1 mms.
		Range: 176—58 mms.
Total	100%	

Dominant Forms by Average %

Grasshoppers	20.20%
Land beetles	13.71%
Caddis (larvae)	13.28%
Ants	11.54%
Cranefly (larvae)	8.17%
All other food	33.10%
Total	100.00%

In October, foraging was essentially the same as for September. The trout continued feeding predominately on terrestrial insects with grasshoppers still in the lead. The same insects—beetles, ants, and caddis were also among the dominant forms taken. Cranefly larvae however, take the place of midge larvae, although

by a very slight margin, as the percentage of midge larvae in the stomachs was 7.96% against the figures given above. It was noted that although the five dominating food organisms were essentially the same, that they made up less of the whole than in previous months. The rest of the food came to 33.10%, which indicated a greater variety being eaten.

NOVEMBER 1931

Aquatic food	45%	Number stomachs: 36
Terrestrial food	55%	Average length of fish: 108.2 mms.
		Range: 180—58 mms.
Total	100%	

Dominant Forms by Average %

Land beetles	18.86%
Mayfly (nymphs)	11.43%
Sowbugs (crustacea)	10.73%
A. Beetles (larvae)	9.03%
Caddis (larvae)	7.26%
All other food	42.69%
Total	100.00%

Although the average percentage of aquatic food was exceeded by land food in November, the aquatic played a more important part than in September. Terrestrial beetles however, formed the highest percentage of any one kind of food. Two unusual items were conspicuous in the November stomachs, namely the terrestrial sowbugs and aquatic beetle larvae.

The food making up the five highest percentage was less significant and a less conspicuous part of the total than for October. All other food eaten came to 42.69%, which showed that the fish were feeding on a wider assortment of animals than in the former month.

DECEMBER 1931

Aquatic food	74%	Number stomachs: 44
Terrestrial	26%	Average length of fish: 104 mms.
		Range: 145—62 mms.
Total	100%	

Dominant Forms by Average %

Midge (larvae)	17.63%
Caddis (larvae pupae)	17.23%
Sowbugs (crustaceans)	13.59%
Mayfly (nymphs)	8.91%
Cranefly (larvae)	7.61%
All other food	35.03%
Total	100.00%

As December marks the return of winter to the New England hills, land food is more difficult to obtain, and the results from the December trout stomachs were not surprising. Sowbugs were

the only land animals at all conspicuous. The December data clearly illustrated the real dependence of trout on the staple aquatic foods—midge larvae, caddis larvae, mayfly nymphs, cranefly larvae and the like.

The monthly food studies have strongly indicated that with regard to food, the limiting factor of a good trout stream is the amount of aquatic insects produced in that stream. During the warm months terrestrial animals make up a considerable proportion of the food eaten, but that produced in the stream itself is never neglected, and the advent of winter forces the fish to make use of aquatic life almost entirely for their sustenance.

YEARLY SUMMARY OF FOOD EATEN

(Average Percentages Computed from Monthly Percentages)

Aquatic Food	Av. %	Terrestrial Food	Av. %
Caddis (larvae, pupae, adults)	20.63	Beetles	7.26
Midge (larvae, pupae)	13.05	Grasshoppers (crickets)	7.14
Mayfly (nymphs-trace adults)	11.82	Ants (trace-bees, wasps)	5.27
Misc. aquatic larvae (Dip. most)	7.27	Misc. land insects	4.07
Cranefly (larvae)	5.24	Earthworms	3.28
Stonefly (nymphs-trace adults)	4.52	Sowbugs (crustaceans)	2.64
Beetles (larvae chiefly)	1.72	Spiders, millepedes, etc.	1.16
Aquatic worms	.73	Caterpillars	1.05
Fishflies, orl flies	.42	Bugs (leaf hoppers chiefly)	.92
Snails	.37	Slugs	.66
Trout eggs	.20	Snow fleas	.01
Water mites	.16	Total	33.46
Salamanders	.16		
Leeches	.15		
Dragonfly (nymphs)	.10		
Total	66.54		

Aquatic food	66.54%
Terrestrial food	33.46%
Total	100.00%

The above table shows the average percentages of the various food items taken during the year. It is seen at once that the percentage of aquatic organisms is practically double that of the terrestrial.

The immature stages of four orders of aquatic insects, the caddis flies (Trichoptera), the true flies (Diptera), the mayflies (Ephemerida) and the stoneflies (Plecoptera), make up the bulk of the food eaten by brook trout in the stream involved. These four orders alone make up 62.53% of the total food. As the remaining aquatic food made up only 4.1% the importance of these four groups of aquatic insects can be readily appreciated.

Of the land forms eaten, beetles (Coleoptera), grasshoppers (Orthoptera) and ants (with trace of bees, wasps-Hymenoptera), were most important, making up over half of the percentage of land organisms eaten.

It can therefore be concluded that trout in the stream involved depend the year around on aquatic food. Second, that insects, both aquatic and terrestrial, make up the bulk of all things eaten. Third, that vertebrate food was negligible and when it occurred consisted of salamanders. No other fish except trout were in the stream, and although specimens were seined with enough size variation to make cannibalism possible, no trace of fish was found in any stomach. None of the trout, however, exceeded eight inches in length and cannibalism usually occurs among much larger fish.

It is significant that there were more fish with empty stomachs during the months of September, October and November than at other times. This appeared to be due to the advent of the spawning season, at which time the trout apparently lost some of their interest in food. The stomachs of twenty-eight adult female trout taken at spawning time were classified as follows:

Empty or lightly filled: 39.3% (Average of 25.6% for entire year).

Moderate to completely filled: 60.7% (Average of 74.4% for entire year).

Thus these results indicate that the activities of spawning cause the fish to feed somewhat less readily than at other times.

Evidence of Egg Eating

Trout eggs were found in the stomachs in a few instances. The eggs, however, made up a very inconsiderable portion of the food, as shown in the following table:

Eggs Eaten

October	1.21%	December	1.02%
November	.11%	January	.09%

SUMMARY

1. 550 wild brook trout were caught with a seine at regular intervals during each month of the year from a quarter-mile section of a Vermont brook. A special effort was made to obtain a large percentage of winter-caught trout.

2. The kind and amount of food taken by these fish was tabulated, the results being expressed in averages of the percentage bulk in the various stomachs.

3. Aquatic food was clearly dominant during the months of January, February, March, April, May, July and December. During the other months of the year terrestrial animals supplied the bulk of the food, but aquatic organisms were never neglected.

4. The dominant aquatic food consisted of fly larvae (Diptera), caddis larvae, pupae and adults (Trichoptera), mayfly nymphs (Ephemerida), and stonefly nymphs (Plecoptera). The dominant terrestrial food consisted of land beetles (Coleoptera), grasshoppers (Orthoptera) and ants (Hymenoptera).

5. Aquatic animals supplied 66.54% of the total food taken during the twelve months, while terrestrial animals made up 33.46%.

6. Insects were the most important items in both land and water food, making up 90.45% of the total.

7. Earthworms and terrestrial sowbugs (Crustaceans) were the principal non-insect food among the land forms. Aquatic food other than insects was too insignificant to be considered.

8. No fish remains were found in any of the stomachs. This was probably due to the fact that no fish over eight inches long were examined. Two brook salamanders comprised the only vertebrates eaten.

9. The advent of the spawning season slowed up feeding to some extent. Sexual excitement rather than a lowered water temperature appeared to be responsible for the fact that more empty stomachs were found in September, October and November than in December, January, February and March.

10. The results of this investigation agree closely with the general findings of Needham in a similar study of fish stomachs from various New York brooks. The observations on seasonal food made in the present paper fit in very nicely with the accepted idea of what constitutes trout food in general.

Bibliography

Atkinson, N. J.

1932. A study of comparative results from stocking barren lakes with rainbow trout. Transactions American Fisheries Society, vol. 62, 1932, pp. 197-201.

Clemens, Wilbert A.

1928. The food of trout from the streams of Oneida County, New York State. Transactions American Fisheries Society, vol. 58, 1928, pp. 183-197.

Harkness, William J. K., and Ricker, William E.

1929. A preliminary study of some trout waters of Ontario. Transactions American Fisheries Society, vol. 59, 1929, pp. 256-267.

Metzelaar, Jan

1928. The food of rainbow trout in Michigan. Transactions American Fisheries Society, vol. 58, 1928, pp. 178-182.

1929. The food of the trout in Michigan. Transactions American Fisheries Society, vol. 59, 1929, pp. 146-152.

Needham, P. R.

1930. Studies on the seasonal food of brook trout. Transactions American Fisheries Society, vol. 60, 1930, pp. 73-88.

Ricker, William E.

1930. Feeding habits of speckled trout in Ontario waters. Transactions American Fisheries Society, vol. 60, 1930, pp. 64-72.

White, H. C.

1930. Some observations on the eastern brook trout (S. fontinalis) of Prince Edward Island. Transactions American Fisheries Society, vol. 60, 1930, pp. 101-108.

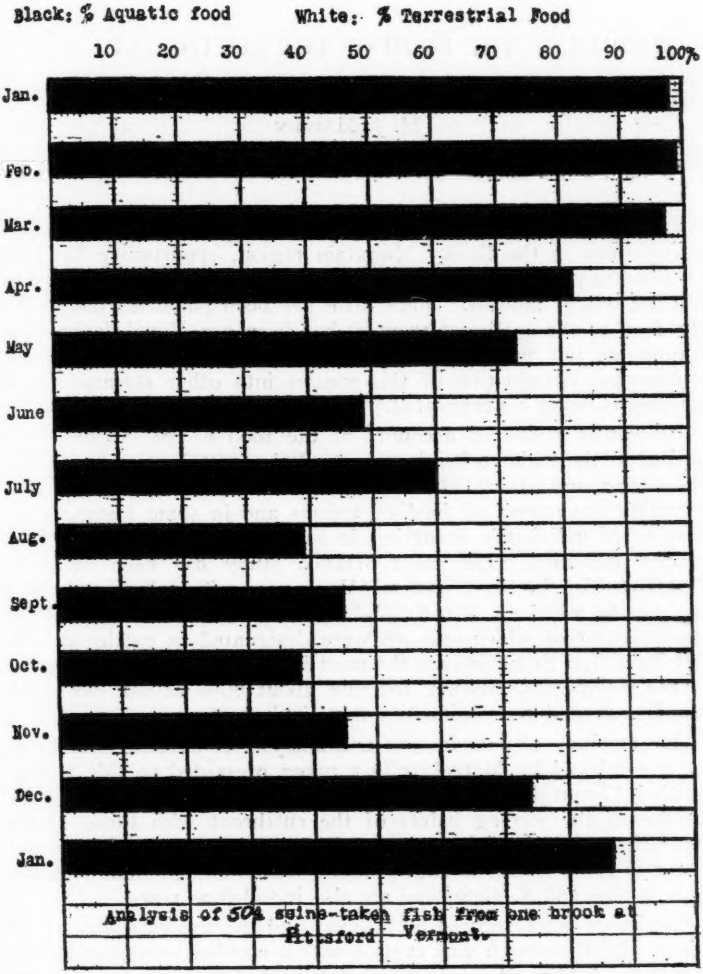

Diagram showing the percentages of aquatic and terrestrial food for each month. Attention is called to the salient fact that in the cold months aquatic food is taken almost exclusively.

STUDIES OF THE FOOD OF THE CUTTHROAT TROUT

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During the past three seasons while engaged in limnological investigations in the Rocky Mountain region, opportunity has been afforded to collect a number of trout stomachs for examination during the winter months. Since little has been published concerning the food of the cutthroat trout, it has been considered desirable to summarize our findings for this Society, particularly since more widespread introduction of this species into other streams of the country is being contemplated.

Previously published accounts of the food of the cutthroat are limited in the main to brief notes by Juday (1907), Snyder (1917), Kemmerer and others (1923) and Muttkowski (1925, 1929), enumerating the orders of food organisms and in some instances the number of individuals occurring in each of several stomachs from various localities. The most detailed study has been made by Muttkowski. In his "Food of Yellowstone Trout" he tabulates analyses by numbers of individuals of food organisms eaten by 148 stream trout of which only 48 were designated as cutthroat. He concludes that Stoneflies are the most important food of this species in the Yellowstone region, forming about 90% of the diet, with Mayflies second and Caddisflies third in importance.

Our methods of examination and analysis of data are similar to those employed by Metzelaar in a paper presented to this Society entitled "Trout Food in Michigan," thus making possible a comparison of the feeding habits of the cutthroat with those of the brook, brown and rainbow trout. The species of cutthroat represented in these studies is largely *Salmo lewisi,* though some stomachs of *S. gibbsii* and *S. pleuriticus* are also included as noted.

Specimens were secured by angling and the use of gill nets and seines. Each stomach was tagged with a number corresponding to that in the field notebook in which date and place of capture, length, weight and sex were recorded. The material was preserved in 5% formaldehyde which was changed several times during the season. Analysis was made by opening the stomach in water, separating and enumerating the types of food and measuring the volume of

the total number of each type by water displacement in a graduate accurate to 0.1 c.c. The data for each trout were placed on a card and filed by locality. Approximately 10% of the stomachs secured were empty and were therefore discarded. About 25% of the stomach contents consisted of small stones, sticks, pine needles and fragments of food which could not be identified without tedious examination by a specialist. This percentage was therefore discarded and was not included in the calculations. It is probably correct to assume that each type of food was represented in this debris in the proportions in which it occurred in recognizable form and therefore the percentages would not be greatly different if each leg, wing, etc., had been identified and assigned to the proper class.

Preliminary study of the analyses showed no significant difference in the food of trout of various sizes except in the case of fish from the lakes of Teton Park. The very obvious change in diet with size made desirable the treatment given in Table 6. Inasmuch as the food supply of lakes and streams differs greatly, separate studies were made for each of these environments. The data from Teton and Glacier Parks are given separately in order to demonstrate similarities and differences in the diet of trout in these two regions.

TABLE 1

Results of examination of stomachs of 48 Cutthroat fry *(S. lewisi)* taken Sept. 9, 1931, in tributary of Jackson Lake, Wyoming, size range 1 to 1⅝ inches.

Food organisms	Number of fry containing these foods	Average number eaten by each fish
Ephemerida: Mayflies		
Nymphs	14	1.1
Adults	1	1.0
Trichoptera: Caddisfly larvae	10	1.3
Plecoptera: Stoneflies		
Nymphs	31	2.0
Adults	2	1.0
Diptera: Two-winged flies		
Midge:		
Larvae	44	10.8
Pupae	40	8.2
Adults	18	1.4
Blackfly, Larvae	1	1.0
Cranefly		
Larvae	1	1.0
Adults	1	1.0
Unidentified Larvae	5	1.2
Coleoptera: Beetle Larvae	8	1.6
Hymenoptera: Ant	1	1.0
Hemiptera: Bugs	10	1.2
Lepidoptera: Moth Larvae	2	1.0
Hydracnia: Water Mites	20	3.9
Arachnida: Spiders	2	1.0
Microcrustacea:		
Copepods	21	4.1
Ostracods	15	3.2
Oligochaeta: Aquatic Worms	8	8.5

TABLE 2

Food organisms eaten by Cutthroat Trout *(S. lewisi)* of streams of Teton Park, Wyoming —from stomach examination of 36 specimens from 4½ to 12½ inches, taken July 20 to August 26, 1931.

Food organisms	Percentage of trout containing this food	Percentage of total volume of food eaten by all trout
Invertebrates		
Ephemerida: Mayflies	94.5%	18.1%
Trichoptera: Caddisflies	69.4	24.5
Plecoptera: Stoneflies	61.1	16.5
Diptera: Two-winged flies	80.6	6.6
Coleoptera: Beetles	41.6	4.4
Hymenoptera: Ants, Bees	83.4	13.2
Hemiptera: Bugs	16.7	1.0
Homoptera: Plant Lice, etc.	11.1	0.1
Lepidoptera: Moth Larvae	16.6	10.8
Arachnida: Spiders, Mites	13.9	0.3
Vertebrates		
Fishes (bait)	2.8	4.5
Total Water Food	100.0	75.0
Total Land Food	24.1	25.0

TABLE 3

Food organisms eaten by Cutthroat Trout *(S. lewisi)* of streams of Glacier Park, Montana—from stomach examination of 37 specimens from 3 1/16 to 10½ inches, taken August 14 to 25, 1932.

Food organisms	Percentage of trout containing this food	Percentage of total volume of food eaten by all trout
Invertebrates		
Ephemerida: Mayflies	45.0%	24.6%
Trichoptera: Caddisflies	15.0	5.2
Plecoptera: Stoneflies	10.0	4.3
Diptera: Two-winged flies	47.5	3.9
Coleoptera: Beetles	35.0	19.6
Hymenoptera: Ants, Bees	37.5	14.9
Hemiptera: Bugs	17.5	8.8
Homoptera: Plant Lice, etc.	12.5	4.8
Arachnida: Spiders, Mites	5.0	2.4
Orthoptera: Grasshoppers	5.0	11.4
Total Water Food	72.5	43.3
Total Land Food	52.5	56.7

TABLE 4.

Food organisms eaten by Cutthroat Trout *(S. lewisi)* of lakes of Teton Park, Wyo.—from stomach examination of 98 specimens from 7½ to 21½ inches, taken July 20 to September 14, 1931.

Food organisms	Percentage of trout containing this food	Percentage of total volume of all food eaten
Invertebrates.		
Ephemerida: Mayflies	20.4%	0.5%
Trichoptera: Caddisflies	19.4	0.7
Plecoptera: Stoneflies	9.2	0.5
Diptera: Two-winged flies	52.0	1.4
Coleoptera: Bettles	25.5	1.5
Hymenoptera: Ants, Bees	43.9	4.2
Hemiptera: Bugs	20.4	0.8
Homoptera: Plant Lice, etc.	9.2	0.4
Orthoptera: Grasshoppers	5.1	0.5
Odonata: Dragon & Damselflies	5.1	1.5
Lepidoptera: Moths	4.1	0.1
Arachnida: Spiders, Mites	3.1	0.1
Mollusca: Clams, Snails	2.0	0.1
Microcrustacea: Plankton	36.7	10.3
Malacostraca: Shrimp	2.0	0.1
Vertebrates.		
Teleostei: Fish	38.8	67.8
Mammalia: Mouse	1.0	9.1
Total Water Food	86.3	81.2
Total Land Food	30.5	18.8

TABLE 5

Food organisms eaten by Cutthroat Trout *(S. lewisi* and *S. gibbsii)* of lakes of Glacier Park, Mont.—from stomach examination of 40 specimens 5½ to 23¼ inches, taken July 3 to September 10, 1932.

Food organisms	Percentage of trout containing this food	Percentage of total volume of food eaten by all trout
Invertebrates.		
Ephemerida: Mayflies	22.7%	11.6%
Trichoptera: Caddisflies	18.1	6.0
Plecoptera: Stoneflies	4.5	0.2
Diptera: Two-winged flies	63.0	16.6
Coleoptera: Beetles	18.1	2.7
Hymenoptera: Ants, Bees	15.9	3.7
Hemiptera: Bugs	15.9	3.3
Orthoptera: Grasshoppers	2.2	0.7
Odonata: Dragon & Damselflies	18.1	9.1
Mollusca: Clams, Snails	11.4	2.2
Microcrustacea: Plankton	25.0	8.6
Malacostraca: Shrimp	31.8	35.3
Total Water Food	88.6	92.4
Total Land Food	22.7	7.6

TABLE 6

Percentage by volume of different classes of food consumed by different size groups of 98 Cutthroat Trout *(S. lewisi)* from lakes of Teton Park and Jackson Lake, Wyoming.

Size range in inches	7½-11½	11½-15½	15½-21½	Average (simple) for groups
Aquatic insects	10.7%	5.5%	1.0%	5.7%
Land insects	35.0	4.6	5.4	15.0
Vertebrates (Fish and 1 mouse)	21.5	82.3*	84.8	62.9
Crustaceans (largely plankton)	32.8	7.6	8.8	16.4
Number of fish	34	38	26	32.6

*Mouse made up 20.1% of food in this class.

Discussion

A study of Table 1 indicates that the diet of the smallest fingerling cutthroats in this typical mountain stream is rather diversified, practically the entire stream population being represented. Only the small, immature forms of the larger species were eaten. The two-winged flies, Diptera, particularly the midges, were taken most frequently and in the largest numbers. Stonefly nymphs proved to be the second most popular food, being found in 31 fry, although the average number consumed was much lower than in the case of the midges. The presence of micro-crustacea is explained by the fact that some individuals for the study were taken from small, almost landlocked pools. A comparison of the study with that of Clemens (1928) shows that the food of the young eastern brook and the cutthroat differ but little, midges being the most important item in each case.

Comparison of Tables 2 and 3 shows that considerable variation in the feeding habits of the same species may occur in rather similar streams of different regions. Caddisflies make up the bulk of the food of cutthroat in streams of Teton Park, although not taken as frequently as other foods; mayflies take chief place by volume in streams of Glacier Park, though second to the two-winged flies in frequency of occurrence. These findings are in contrast to those of Muttkowski for trout in Yellowstone Park, as

previously mentioned. Aquatic food was found in 100% of the stomachs of Teton Park trout and made up 75% of the total volume of food consumed in contrast to 72.5% and 43.3% respectively in the case of Glacier Park trout. The latter being taken in late August when terrestrial foods are most abundant may partly explain this variation.

A study of Tables 4 and 5 also demonstrates the variation in the food of the cutthroat, depending upon the type of environment. In the lakes of Teton Park which are largely deep with rocky or sandy shore and little aquatic vegetation, though richly supplied with minnow life, fish made up 67.8% of the volume of the food though occurring in only 38.8% of the stomachs. The lakes in Glacier Park from which the bulk of specimens of cutthroat were taken for stomach examination are relatively shallow and contain considerable plant life. This undoubtedly accounts for the greater importance of dragonflies and shrimp as food for these trout. Minnows do not occur in the majority of Glacier Park lakes, which probably accounts for their absence in the diet of fish from this region.

Table 6 demonstrates a distinct change in diet as the cutthroat increases in size. Up to 11½ inches, plankton crustacea form an important article of diet, second only to surface food in the form of land insects. Fish had been eaten by nine individuals. The next size group shows a greater preference for fish, 61.2% by volume, with corresponding decreases in other types of food, notably land insects and plankton. The largest size class had a diet almost exclusively of fish, the other types of food increasing slightly in importance with the exception of the aquatic insects. The average for the three groups indicates the importance of forage fish in trout lakes and reaffirms the value of plankton as a food, particularly for the smaller sizes. A comparison with Metzalaar's (1929) studies of brook, brown and rainbow trout, while not strictly comparable since his were streams fish, does show, however, the same decrease in importance of land and aquatic insects and a similar though more striking increase in fish consumption as the cutthroat trout grow in size. Where small fish are available, it is evident that the cutthroats utilize them.

Of the 65 fish eaten, 27 were identified as the silver side minnow (*Cheonda hydrophlox*), 1 sucker (*Catostomous ardens*), 4 Rocky Mountain whitefish (*Prosopium williamsoni*), 1 trout (species unknown), and 30 young fish too badly digested to identify but the majority appeared to be the silver side minnows. This is in conformity with reports of Snyder (1927) and of Kemmerer *et al* (1923) concerning the cutthroat of Pyramid Lake, Nevada, and Bear Lake, Utah.

In regard to the diet of fish, Muttkowski (1925) has well stated that they "are opportunists as far as their food is concerned. They eat what animal food is available, regardless of the origin."

In contrast to the foregoing, examination of some specimens of cutthroats from other regions reveals quite dissimilar diets. Four trout (*S. pleuriticus*) 11¾ to 14½ inches from the Strawberry Reservoir, Utah, had eaten nothing but midge (*Chironomus*) larvae and pupae, one having devoured 900 of these insects. Fish-

ermen report that all the stomachs examined by them are full of these red or green "worms," as they call them. Samples of the food here reveal that the midge is the dominant organism.

Thirty stomachs of the red-side cutthroat (*S. gibbsii*) from the Middle Fork of the Salmon River, Idaho, were examined in the field. Approximately half contained 100% snails in large numbers. The balance had eaten from 10% to 50% snails, the remaining stomach contents consisting of caddis and stoneflies, fish (1 minnow and 1 sculpin) and eggs of the native whitefish. The fish and fish eggs were found in 10% of the stomachs examined. In this stream snails were the dominant organism, being present everywhere in the stream, even on the rocks in fairly rapid water. These were identified by Mr. Elmer Berry of the University of Utah as *Stagnicola apicina* and *Physa virgata*.

Summarizing studies of the food of the cutthroat, it may be said that their diet is similar to that of the other species of trout previously studied, varying greatly with different environments. Where forage fish are available these forms are increasingly important items as the size of the trout increases.

Bibliography

Clemens, W. A.
1928. The food of trout from the streams of Oneida county, New York State. Trans. Am. Fish. Soc., Vol. 58.

Juday, Chancey
1907. A study of Twin Lakes, Colorado, with especial consideration of the food of the trout. Bull. Bur. Fish., 1907, 26, 147-178. pl.

Kemmerer, George, J. F. Bovard and W. R. Boorman
1923. Northwestern lakes of the United States; biological and chemical studies with reference to possibilities in production of fish. Bull. Bur. Fish., Vol. XXXXIX, 1923-24.

Metzelaar, Jan
1929. Trout food in Michigan. Trans. Am. Fish. Soc., Vol. 59.

Muttkowski, R. A.
1925. Food of the Yellowstone Trout. Roosevelt Wild Life Bull. Vol. 2, No. 4.

———
1929. The ecology of trout streams in Yellowstone National Park. Roosevelt Wild Life Annals, Vol. 2, No. 2.

Snyder, J. O.
1917. The fishes of the Lahontan system of Nevada and northeastern California. Bull. Bur. Fish., Vol. XXXV, 1915-16 (1917).

LOW WATER TEMPERATURE, A LIMITING FACTOR IN THE SUCCESSFUL PRODUCTION OF TROUT IN NATURAL WATERS

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The importance of proper water temperature in a hatchery supply has long been recognized by fish culturists. Leach (1923) recommends that the supply for hatching should be within a temperature range of from 42° to 58° F., with best results from 48° to 54° F. Davis (1929) states that (fingerling) "trout appear to grow most rapidly between 55° and 60° F."

Belding (1928) makes the statement that "irrespective of food supply fish culturists have demonstrated that within certain limits fry and fingerling trout grow more slowly in cold water than in warm." However, to the writer's knowledge, no carefully controlled experiments have ever been conducted with trout which would show the exact food consumption and growth at the lower temperatures. Such experiments have been carried out by Hathaway (1927) and later by Markus (1932) using warm water fishes. They have demonstrated conclusively that a certain temperature range is necessary for feeding and proper growth. Such a series of experiments with different species of trout would be most enlightening and would be of great value both to the fish culturist and to the man engaged in the formulation of systematic stocking policies for public and private waters.

Embody (1921) called the attention of this Society to the limiting effect of high temperatures in determining the suitability of water for different species of trout. From experiments and field observations he determined the upper limits of tolerance of brook, brown, and rainbow trout. Later (1926 and 1927) he published highly useful tables correlating air and water temperature in streams of New York State, making it possible to estimate the probable maximum which a stream would attain during the hottest period of the summer.

Other workers have discussed this problem of high temperature and its effect upon successful introduction of trout, notably Creaser (1930) and Belding (1928), but the possibility that low water temperature might be almost as important, at least in certain sections of the country, has received little attention. Hubbs, Greeley and Tarzwell (1932) observe that "the coldest spring water, issuing from the ground at temperatures of 43° to 52° F., while habitable by trout and particularly well suited to their spawning, is much less conducive to growth than considerably warmer water (60° to 70° F)." The author (Hazzard, 1932) has attributed the slow growth of brook trout in certain New York State streams to low water temperature

which together with the low rate of removal and highly suitable spawning conditions has resulted in over-population with small trout.

During the course of biological investigations conducted by the U. S. Bureau of Fisheries in the National Parks and National Forests of the Rocky Mountain region, numerous other examples of slow growth apparently attributable to cold water have come to the writer's attention and have led to the belief that many streams and some lakes actually remain too cold to make planting worthwhile.

A rather careful record of plantings in Glacier National Park since 1912 has been kept by the Bureau and the National Park Service. Comparison of this with data secured by the Survey of 1932 reveals that some streams and lakes have been stocked with little or no success and, furthermore, that these waters are, without exception, low in temperature, rarely, if ever, attaining or exceeding 55° F. even during the height of the summer. On the other hand, the productive waters exhibited summer temperatures ranging from 54° to 70° F. during the months of July, August and September. The lakes and streams in this park having the warmest waters (all well below the upper limits of tolerance) proved to be the most productive of trout. It was a conclusion of the Survey that the poor stream fishing found here is due primarily to this factor. The lakes afford much better results though many are high and, in some instances, glacier fed. However, the great majority of these are situated so that they receive considerable sunlight and in addition have a large percentage of shallow water which is quickly warmed.

A description of one of the river systems in Glacier Park may serve to illustrate. This river heads in a lake fed by permanent snow fields and is notorious for its thin, poor-fighting rainbows. Although sufficient data have not been accumulated to arrive at a standard, nevertheless from the writer's experience, the condition factor (Hecht, 1916) of these fish is low, averaging 1.107 for five specimens taken. This substantiates the reports of thin fish. Late spawning, apparently just beginning about June 21 and scarcely completed at the second visit on July 13, is undoubtedly a factor, but anglers familiar with the lake report that the trout here are always poor. Surface temperatures at the outlet late in the day were recorded as follows: June 21, 45°, July 13, 55.7°, August 12, 56.0°, Sept. 7, 56° F. Another lake very similar except that it contained more shallow water and a richer food supply exhibited the same phenomenon. The average of the condition factor for 13 fish taken here July 22, was 1.250. As in the other lake, the immature fish were fat; those that had spawned were poor. The possibility is suggested that once these rainbows have spawned, the low water temperature and consequently low metabolic activity prevents them from recovering "condition," even though an ample food supply is present.

In a small, shallow pond below the first lake mentioned, good

catches of fat rainbows were reported. Though none was taken by our party, the fish seen were evidently in good condition. Immediately below this pond are two miles of stream of average pool and food conditions, heavily shaded and receiving several sizeable, cold tributaries. The second lake in the system is then encountered, followed by another three miles of stream which empties into the lower lake. The two lower lakes contain well conditioned cutthroat, rainbow and eastern brook trout. Only a few small trout are found in this river except immediately below the lakes and below a series of beaver ponds above the lower lake. No barriers prevent the movement of fish from these lakes into the stream above for considerable distances, except the proposed barrier of low temperature. Other conditions are apparently highly suitable for trout but those actually present are too small to provide worthwhile fishing *notwithstanding consistent planting* and some contribution from natural spawning.

Another river system close by presents parallel conditions. Ample stocking over a period of years has resulted in providing fishing only in the lakes and in one section of the river fed by beaver ponds. Temperatures taken at the inlet and outlet of one pond less than ¼ acre showed a rise of 4° F. Incidentally this indicates the value of the industrious beaver to trout streams in the Rocky Mountain region.

The foregoing is presented partly with the hope that some worker having the necessary facilities will be inspired to perform experiments with trout paralleling those of Hathaway and Markus on warm-water fishes. The number of waters in the west where this problem is in evidence is believed by the writer to be considerable. Experiments indicating the lower limits of temperature at which successful growth for different species occurs would be of great value in determining the stocking policy for the colder waters of this region and would prevent a waste of time, money and effort.

Bibliography

Belding, David L.

1928. Water temperature and fish life. Trans. Am. Fish. Soc., Vol. 58.

Creaser, Charles W.

1930. Relative importance of hydrogen ion concentration, temperature, dissolved oxygen, carbon dioxide tension on habitat selection of brook trout. Ecology, Vol. XI., 1930.

Davis, H. S.

1929. Care and diseases of trout. Bur. Fish. Doc. No. 1061.

Embody, G. C.
1921. Concerning high water temperature and trout. Trans. Am. Fish. Soc., Vol. 51.
1926. Biological survey of the Genesee River. Sup. to Ann. Rept. N. Y. S. Cons. Dept.
1927. Biological survey of the Oswego River System. Sup. to Ann. Rept. of N. Y. S. Cons. Dept.

Hathaway, Edward S.
1927. The relation of temperature to the quantity of food consumed by fishes. Ecology, Vol. 8.

Hazzard, A. S.
1932. Some phases of the life history of the eastern brook trout, *Salvelinus fontinalis* Mitchell. Trans. Am. Fish. Soc., Vol. 62.

Hecht, Selig
1916. Form and growth of fishes. Journ. of Morphol, Vol. 27.

Hubbs, Carl L., Greeley, John R. and Tarzwell, Clarence M.
1932. Methods for the improvement of Michigan trout treams. Bull, No. 1, Inst. for Fish Research.

Leach, Glen C.
1923. Artificial propagation of brook trout and rainbow trout, with notes on three other species. Bur. Fish., Doc. No. 955.

Markus, Henry C.
1932. The extent to which temperature changes influence food consumption in large-mouth bass (*Huro floridana*). Trans. Am. Fish. Soc., Vol. 62.

THE OXYGEN CONSUMPTION OF LARGEMOUTH BLACK BASS (HURO FLORIDANA) FINGERLING

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Introduction

Although quite a number of papers dealing with the oxygen consumption of fishes and other cold-blooded animals have appeared in recent years, none of these authors except Burdick (1932-33) who investigated the oxygen consumption of the white crappie, and the channel cat, has concerned himself with the oxygen consumption of our common pond-fishes. It seemed warranted, therefore, that the oxygen consumption of such a popular fish as the largemouth black bass should be investigated. It seemed logical also that the senior author of this report should make this investigation. Having studied (1) the effect of changes in pH (Wiebe 1931); (2) the ability to survive prolonged exposure to abnormally high concentration of dissolved oxygen (Wiebe 1932); (3) the effect of high concentration of oxygen (Wiebe 1933); and (4) the ability to extract oxygen from the water at different hydrogen-ion concentrations (Wiebe et. al. 1934). The next logical step seemed to be the exact measurement of oxygen consumption at (1) different hydrogen-ion concentration, (2) different oxygen tension, and (3) at different temperature. This has been attempted in the present paper.

These experiments were performed in the Department of Zoology at the University of Iowa and it is a pleasure to acknowledge the courtesy of Dr. Bodine in making the facilities of the department available for this work. It is also a pleasure to acknowledge the suggestions and criticisms of Mr. Burdick, a student in the department.

Method

The method used in these experiments is that described by Keys (1930). This method involves a flowing water system. It is undoubtedly superior to the older methods and the results obtained thereby should be less subject to error. For a description of the method the reader is referred to the papers by Keys.

The size of fish used is indicated in each section of this paper. This is important since Keys found that if fish differed in weight by more than 10% the results were no longer comparable. Burdick (unpublished data) found that in the channel cat the oxygen con-

sumption per gram of fish was inversely proportional to the weight of the fish. The smaller fish using much more oxygen per unit weight than the larger fish. Our data, although not analyzed with that purpose in view, show the same tendency.

It should likewise be noted that the oxygen consumption measured here is that of animals that had not been fed for three days.

Experimental Data (Effect of pH)

In Figure 1 there are given a series of curves showing the oxygen consumption at different pH values. The bass used in this experiment ranged in weight from 13.5 to 15 grams. The temperature was kept constant at 26°C. The oxygen tension varied from 6.2 to 6.5 C.C. per litre. That these variations in oxygen are insignificant is shown by the result recorded below under the effect of varying oxygen tension. The fish were left in the experimental chambers for 13 hours. Duplicate samples of the ingoing as well as of the outgoing water were taken every two hours. Each point on the curve is the average of 12 individual samples and represent the average consumption for six fish.

The curves in Figure 1 show that it takes from seven to nine hours before the minimum consumption of oxygen occurs. Experiments continued for periods of less than eight hours would, therefore, fail to give minimum readings. The results also show that for any given lot of fish the consumption is fairly constant after the minimum value has been attained. The results, however, fail to show any very constant effect of pH. The rate of oxygen consumption at pH 9.4 is definitely higher than at pH 9.1. However, at pH 9.6 and at pH 9.7 the oxygen consumption while higher than at pH 9.1 is less than at pH 9.4. At pH 8.1 the oxygen consumption is almost equal to that at pH 9.6 and at pH 7.5 to that at pH 9.4. Hence the results show no constant relationship between oxygen consumption and the reaction of the water. Any variations in the oxygen consumption is perhaps to be attributed to a difference in the behavior of the different groups of fish rather than to any effect produced by the difference in hydrogen-ion concentrations. The actual amount of oxygen consumed within this pH range expressed in cubic centimeters per 100 grams of fish per hour varies from 12.5 C. C. to 14.4 C. C. This lack of correlation between the oxygen consumption is not in agreement with the results of Wells (1913-1918), and Shelford and Powers (1915). These investigators reported that fish were very sensitive to very small changes in the pH of the water. It might be expected, therefore, that a marked change in pH would have a very definite effect upon the oxygen consumption. In another paper by the present author et. al. (this paper will appear in the Journal of Physiology and Zoology), it has been shown that the pH has a very marked effect

upon the ability of fish to extract oxygen from the water at low tension. This is true especially of the bluegill and some of the minnows. That is, in water that is either abnormally acid or abnormally alkaline fish die at a much higher concentration of oxygen than when the water has a normal reaction, i. e., pH 6.5—9.0 in the case of black bass. The fact, however, that fish under these conditions die at a higher oxygen concentration may not necessarily indicate an increased oxygen consumption, but rather an impairment of the respiratory mechanism.

Effect of Oxygen Tension upon Oxygen Consumption

In table 1 there are recorded the results of several experiments performed to show the effect of oxygen tension. It will be noticed in the table that the same fish or group of fish were used at different tensions. In experiment one two fish were used at three different oxygen tensions, namely: 4.4 C. C. per litre, 6.5 C. C. per litre, and 10.6 C. C. per litre. Taking the 4.4 C. C. per litre as the initial tension and designating it 100% the two higher tensions are 147.7% and 290.9% of the initial tension. This relatively large increase in oxygen tension resulted only in a 3% and 4% increase in oxygen consumption. In experiment 2 one fish weighing 41 grams was used. Here an increase in tension of 47.7% and 140.9% increased the consumption 4% and 7% respectively. In experiment 3 five fish ranging from 42-46 grams in weight were used. Here increases in tension of 23%, 37% and 109% produced increases in consumption of 0%, 3% and minus 9%, respectively. In experiment 4 five fish of the same weight as in 3 were used. Variations in tension of 12% and 40% changed the consumption by 0% and 1%, respectively. In experiment 5 one fish weighing 73 grams used 3% less oxygen when the tension was increased from 5.5 C. C. per litre to 8.8 C. C. per litre or of 60%.

The experiments on the effect of tension were all performed at 20°C and a hydrogen-ion concentration of pH 7.5.

The results of these experiments show that there is no direct relationship between oxygen tension and oxygen consumption. The results, moreover, are in agreement with those of several other investigations of the subject of respiration in fishes and in other poikilotherms.

Henze (1910) found that in *Coris* and *Sargus annularis* the oxygen consumption was independent of the tension. Winterstein (1908) reached the same conclusion in respect to the fresh-water fish *Leuciscus*. Gaarder (1819) working with the fish, *Cyprinus carpie,* under urethane narcosis concluded, "Der Sauerstoffverbrauch des Fisches steigt langsam mit einem wachsenden Drucke des im Wasser Gelosten Sauerstoffs. Dieses Ansteigen ist aber so schwach, dass bei kleiner Anderungen im Drucke des im Wasser Gelosten Sauerstoffs,

was unter normalen Verhaltnissen im allgemeinen der Fall ist, der Stoffwechsel praktisch alsunabhangig von dem Sauerstoffdrucke betrachtet werden kann."

Toryu (1927) found that in the goldfish, *Carassius auratus,* the oxygen consumption was independent of the tension. Keys (1930) reported the same results for the Pacific Marine Killifish, *Fundulus parvipinnis.*

Several authors have reported similar results for invertebrates. Hyman (1920) and Buchanan (1931) found that the oxygen consumption in *Planaria doroto cephala* was independent of the tension. Hyman (1932) obtained the same results for the marine Annelid *Nereis virens.* Heistand (1931) reported that for dragonfly nymphs and caddis fly larvae the oxygen consumption was independent of tension over a wide range. Experiments with crayfish gave similar results. Nomura (1926), however, found that in the sea cucumber, *Caudinia,* the oxygen consumption, "is at every instance proportional to the oxygen tension." As Keys says, "such divergencies might be expected in widely differing forms, but in some cases different authors report diametrically opposite results from experiments with similar animals." Amberson (1928) and Kalmses (1928) for instance, reported such contradictory results for *Paramecium.* The former found that in this species the oxygen consumption was independent of tension, whereas, the latter reported that the consumption was directly proportional to the tension.

The conclusion is probably warranted that in a majority of cold-blooded animals the oxygen consumption is independent of oxygen tension and that after the normal requirements of organisms have been satisfied the rate of respiration is regulated largely by the organism itself. The temperature will, of course, modify oxygen consumption.

Effect of Temperature Upon Oxygen Consumption

In table 2 are recorded the results of a few experiments performed to determine the effect of temperature upon oxygen consumption. During these experiments the pH and the oxygen tension were kept constant. In experiment 1 and 2 the same fish were used at three different temperatures, namely, 15°C, 20°C and 25°C. In the remainder of the experiments a different lot of fish was used for each experiment. Experiment 1 shows that in the case of fish weighing 66.5 to 68 grams the oxygen consumption at 20°C was 177 per cent of the consumption at 15°C and at 25°C the oxygen consumption was 282 per cent of that at 15°C. For experiment 2 the oxygen consumption for fish weighing 38.5 to 42 grams at 20° was 153 per cent of that at 15°C, and at 25°C the oxygen consumption was 282 per cent of that at 15°C. These results are in accord with Vant Hoff's law, namely: That for any chemical change the rate of reaction is increased between

two and three fold for every 10°C increase in temperature. Experiments 1 and 2 were performed at pH 7.5.

In the remainder of the experiments fish weighing 13 to 14 grams were used. The results show that at 26°C the oxygen consumption was 164 per cent of that at 20°C. These last two experiments were performed at pH 8.5 and 9.0 respectively, but the difference in pH did not appear to influence the temperature effect.

The results obtained by the writers on the effect of temperature upon oxygen consumption in black bass are in agreement with the findings of Markus (1932) who studied the effect of temperature upon the rate of digestion in black bass. Linderstedt (1914) reported similar results from experiments of several species of fresh water fish studied in Germany.

SUMMARY

The basal metabolism of the largemouth black bass has been investigated and the following results were obtained:

(1) There is no constant relationship between the oxygen consumption and the reaction of the water.

(2) The oxygen consumption appears to be independent of oxygen tension at least within the range of tension investigated.

(3) The temperature coefficient for oxygen consumption lies between two and three.

LITERATURE CITED

(1) Amberson, Wm. R., 1929—The influence of oxygen tension upon the respiration of unicellular organisms. Biol. Bull., Vol. 55.

(2) Gaarder, T., 1918—Ueber den Einfluss des Sauerstoffdruckes auf den Stoffwechsel II. Nach Versuchen an Karpfen Biochem. Zeitschr., Vol. 89.

(3) Heistand, W. D., 1931—The influence of varying tension of oxygen upon the respiratory metabolism of certain aquatic insects and the crayfish. Physiol. Zool., Vol. 4.

(4) Henze, Mr., 1910—Uber den Einfluss des Sauerstoffdruckes auf den Gaswechsel einiger Meerestieren. Biochem Zeitschr., Vol. 26.

(5) Kalmus, H., 1928—Untersuchungen ueber die Atmung von Paramecium Candatum. Zeitschr. Vergleich. Physiol.

(6) Hyman, Libbie H., 1930—The effect of oxygen tension on oxygen consumption in Planaria and some echinoderms. Physiol. Zool., Vol. 2.

(7) Keys, Ancel B.—The measurement of the respiratory exchange of aquatic animals. Biol. Bull., Vol. 59.

(8) Lindstedt, P., 1914—Paper in Zeistschrift fuer Fischerei. Vol. 14.

(9) Nomura, S., 1926—The influence of oxygen tension on the rate of oxygen consumption in Candinia. Sci. Reft. Tohoken Inf. Unio. (2).

(10) Shelford, V. E., and Powers, E. B., 1915—An experimental study of the movements of herring and other fishes. Biol. Bull., Vol. 28.

(11) Toryus, Yoshiyerki, 1927—Respiratory exchange in *Carassius auratus* and the Geseons exchange of the air bladder. Sci. Reft. Tohoken Inf. Unio. Sec. 4, 3, (1).

(12) Wells, M. M., 1913—The resistance of fishes to different concentrations and combinations of oxygen and carbon dioxide. Biol. Bull., Vol. 25.

(13) Wells, M. M., 1918—The reactions and resistance of fishes to carbon dioxide and carbon monoxide. Bull. Illinois State Lab. Nat. Hist., Vol. II, part 8.

(14) Wiebe, A. H., 1931—Notes on the exposure of several species of pond fishes to sudden changes in pH. Trans. Amer. Mic. Soc., Vol. 50.

(15) Weibe, A. H., and McGavock, A. M., 1932—The ability of several species of fishes to survive on prolonged exposure at abnormally high concentrations of dissolved oxygen. Trans. Amer. Fish. Soc., Vol. 62.

(16) Weibe, A. H., and McGavock, A. M., 1933—The effect of high concentrations of dissolved oxygen on several species of pond fishes. Ohio Jour. of Sci., Vol. 33.

(17) Weibe, A. H., McGavock, A. M., Fuller, A. C., and Markus, Henry C., 1934—The ability of fresh water fish to extract oxygen at different hydrogen-ion concentrations. Physical Zool., Vol. 7.

(18) Winterstein, T., 1908—Beitraege zur Kenntnis der Fischat mung. Pflueger's Arch. ges. Physiol., Vol. 125.

TABLE 1

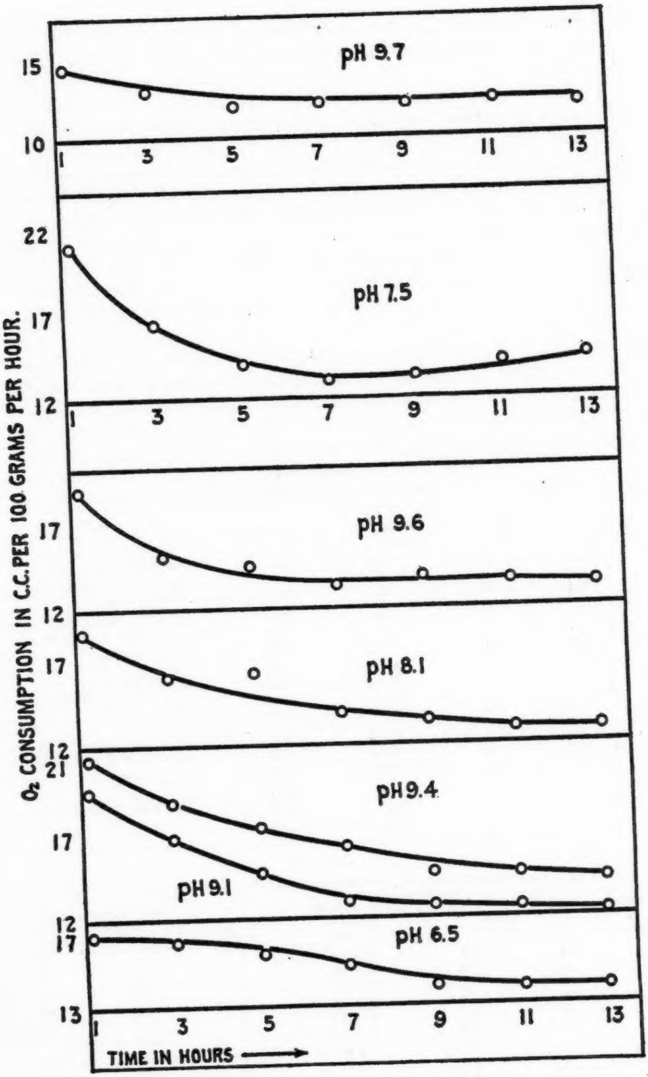
Effects of O_2 Tension upon O_2 Consumption at 20°C and pH 7.5

	O_2 Tension in cc. per litre	No. of fish used	Size of fish used Grams	O_2 consumption in cc. per 100 grams per hour CC.	Per cent	
1	4.4	2	67	4.7	100	The same pair of fish for 3 different tensions.
	6.5	2	67	4.8	103	
	10.6	2	67	4.9	104	
2	4.4	1	41	5.15	100	The same pair of fish for 3 different tensions.
	6.5	1	41	5.37	104	
	10.6	1	41	5.54	107	
3	4.3	5	42-46	6.32	100	The same fish used for 4 different tensions.
	5.3	5	42-46	6.33	100	
	5.9	5	42-46	6.53	103	
	9.0m	5	42-46	5.64	91	
4	6.4	5	42-46	5.86	100	The same fish used for 3 different tensions.
	7.2	4	42-46	5.87	100	
	9.0	5	42-46	5.93	101	
5	5.5	1	73	5.59	100	The same fish.
	8.8	1	73	5.92	97	
6	8.4	5	42-46	5.66		

TABLE 2

Effect of Temperature upon O_2 Consumption at O_2 Tension of 6.1 cc. per litre

	Temperature °C Degrees	No. of fish used	pH	Size of fish used Grams	No of trials	O_2 consumed per 100 grams per hour CC.	Per cent	
1	15	3	7.5	66.5-68	3	2.74	100	The same fish
	20	3	7.5	66.5-68	2	4.86	177	
	25	3	7.5	66.5-68	2	7.74	282	
2	15	3	7.5	38.5-42	2	4.12	100	The same fish
	20	3	7.5	38.5-42	2	6.30	153	
	25	3	7.5	38.5-42	2	9.65	234	
3	20	4	9.0	13-14	3	7.63	100	
4	26	6	9.0	13-14	3	12.56	164	
5	20	4	8.5	13-14	3	7.49	100	
6	26	6	8.5	13-14	3	12.23	164	


pH 9.7
pH 7.5
pH 9.6
pH 8.1
pH 9.4
pH 9.1
pH 6.5
O_2 CONSUMPTION IN C.C. PER 100 GRAMS PER HOUR.
TIME IN HOURS

FISH METABOLISM UNDER INCREASING TEMPERATURE

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That the metabolism of a cold-blooded animal increases as the temperature of its environment is increased is a maxim so firmly rooted in the minds of most biologists that it may seem wanton to explore the question again. Nevertheless, a careful search of the literature shows that most of the experiments to determine the metabolism of fishes under changing temperature conditions have been done on fishes which have been narcotized or rendered abnormal in some manner. The few data which have been obtained in experiments on relatively normal fishes differ from the results obtained from abnormal fishes in a manner which may be significant. It is the purpose of this paper to report on a series of experiments which were done to ascertain the changes which occur in the metabolism of normal fishes as the temperature of the water in which they are swimming is increased.

The two fishes in this report are the black bullhead (*Ameirus melas*) and the largemouth black bass (*Aplites salmoides*). These two are chosen because they are so different in their ecology and because they are of particular interest to practical fishery. The black bullhead is a nocturnally active fish which is almost never taken on a hook and line when the temperature of the water is low. The largemouth black bass has its periods of activity in the early morning and evening of the day. It remains active during the entire winter season and will take a baited hook when the ice covers the water.

However, certain premises must be laid down to serve as cornerstones before it is possible to approach the main problem of this paper.

Before there can be any discussion about the changes of the temperature of the water in which the animal is swimming, the relationship which exists between the temperature of the fish's body and the water must be known. Body temperature of fishes has had its full share of investigation and has produced many conflicting results. But as methods for determining temperature have refined and investigators have become more careful in their handling of the fishes, the results have reached a greater uniformity.

By means of copper-constantan thermocouples and a galvanometer which was sensitive enough to register one one-hundredth of

a degree Centigrade, the body temperature of ten species of fishes[1] was compared with the temperature of the water in which the fishes were swimming. One junction of the thermocouple was in the stomach of the fish, while the other junction was just outside the mouth. The thermocouples caused no visible ill effects and some of the fishes kept the junction in their stomachs for long periods of time. The experiments were done at temperatures which varied from zero to thirty-five degrees Centigrade.

The results of these tests coincide with the conclusions of Regnard[2] and confirm the statement of Rogers[3] that the body temperature of a cold-blooded animal is the same as its surrounding medium. The body temperature of a fish is the same as the temperature of the water as long as the fish is quiescent. Any stimulus may cause a reaction on the part of the fish which will produce an increase in the temperature of the fish's body. The black bullhead will show an increase in body temperature if a light is flashed on it. The passage of a shadow by the aquarium in which they are kept will cause an increase in the body temperature of the sunfish and the perch. However, as the fish swims quietly in the water there is uniformity between the body temperature of the fish and the temperature of the water.

Therefore, the first premise which will serve as a cornerstone to our principal discussion is that the body temperature of a fish is the same as the temperature of the water which is surrounding it. If the fish is quiet we may accept the temperature of the water as the temperature of the fish's body.

A second premise which must be laid down is relative to the constancy of the metabolic rate of a fish during the daily period. It is obvious to anyone who has observed fishes that they have periods of activity interspersed with periods of relative quiet. During these periods of activity it is only logical to suppose that the metabolic rate of the fish is higher than during periods of rest. A series of experiments was done to test for the daily fluctuations in the oxygen consumption of fishes.

An apparatus similar to the one described by Keyes[4] was constructed. This allowed a constant supply of water to pass through three experimental chambers and a control tube. By subtracting the amount of oxygen in the water which came from the experimental chambers, after having passed over the fish, from the amount of oxygen in the water which came from the control

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[1] Bowfin (*Amia calva*), carp (*Cyprinus carpio*), common sucker (*Castostomus commersonii*), channel cat (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), black crappie (*Pomoxis sparoides*), white crappie (*Pomoxis annularis*), blue gill (*Lepomis pallidus*), yellow perch (*Perca flavescens*), warmouth bass (*Chaenobryttus gulosus*).

[2] Regnard, M. P.—Compte Rendus Hebdomadaires Des Seances et Memoires de la Societe de Biologie, 1895. Tome II., p. 651.

[3] Rogers, C. G.—Textbook of Comparative Physiology, 1927. McGraw-Hill, New York. Pp. 352-355.

[4] Keys, A. B.—Biological Bulletin, 1930. Vol. 59, No. 2. Pp. 187-198.

tube, the amount of oxygen consumed by the fish could be determined. Samples were taken every hour for twenty-four consecutive hours.

The daily oxygen consumption of the black bullhead and the largemouth black bass show definite daily rhythms which are specific for each species of fish and these daily rhythms of oxygen consumption coincide quite closely with the known activity rhythms of these fishes.

At midnight the oxygen consumption of the black bullhead is declining from its daily maximum and continues to decrease until 4 A. M., when there is a slight increase which is followed by another decrease until nine in the morning. A slight increase between 10 and 11 A. M. is followed by a decrease to the daily minimum which occurs at about 2 P. M. From 2 P. M. until 11 P. M. there is a general increase in oxygen consumption which is characteristically irregular between 7 and 9 P. M. Between 11 P. M. and midnight is the daily maximum oxygen consumption for the black bullhead.

The daily oxygen consumption of the largemouth black bass shows two high points: one about 6 o'clock in the morning, and another at 9 in the evening. From midnight until 6 A. M. there is a rather sharp rise which is followed by an equally sharp fall until noon. From noon until 9 P. M. there is a general increase which is followed by a relatively quick drop until midnight.

These daily rhythms in oxygen consumption must be taken into consideration if the results of the experiments with increasing temperatures are to be valid. In order to obtain comparable data it is necessary that the determinations of metabolic rate should be made at the same time each day.

The amount of oxygen consumed by an animal has always been considered as a true index to the metabolic rate of the animal. In aquatic animals it is the only practical method of determining the relative metabolism.

The same apparatus which was used in the determination of the daily rhythms of oxygen consumption was used in determining the changes in the metabolic rate as the temperature was changed. The fishes were placed in the experimental chambers and allowed to remain there throughout the experiment. The chambers were covered with cloths to minimize the possibility of stimulation from outside. The oxygen was determined by the Winkler method. As soon as the determination at one temperature had been made, the temperature of the water was changed and then held at the next temperature for twenty-two hours before the subsequent determination was made. Because of mechanical and physical difficulties the range of temperatures which were used in these experiments was limited to between 8° and 22° Centigrade. However, it is

probably between these temperatures that the fish spends most of its active life.

Three black bullheads were tested and gave almost identical results. At eight degrees Centigrade the oxygen consumption is at a low point. It increases very rapidly as the temperature is increased from eight degrees to twelve degrees. However, as the temperature is increased from twelve degrees to fifteen degrees Centigrade, the oxygen consumption of the black bullheads decreases. This decrease is so marked that at fifteen degrees the fishes were consuming less than half the oxygen which was being consumed at twelve degrees Centigrade. From 15°C. to 20°C. there is an increase in the amount of the oxygen consumed, while above 20°C. there seems to be an indication of another decline in the oxygen consumption of the black bullhead.

The curves of the three largemouth black bass which were tested, have the same general contour as those of the black bullhead. They are not as steep in their rises and falls but the critical points fall within one degree of those of the preceding fishes.

There is one difference which is of some ecological significance. At the low temperatures, between 8° and 9°C., the oxygen consumption of the largemouth black bass is high instead of low as is the case of the black bullhead. At these temperatures the average oxygen consumption of the bass is as great as at any time during the experiment. When the bass were observed at these temperatures they were in a state of activity. Their pectoral fins were in motion and the fishes were moving from side to side in the experimental chambers.

Between nine and ten degrees Centigrade there is a decrease in the amount of oxygen consumed by the bass, which is followed by a slight rise between 10° and 13° C. At 14.7° C. the oxygen consumption is appreciably lower than at 13° C. From 15° to 19° C. there is an increase in the amount of oxygen consumed by the largemouth black bass.

Were it not for the uniformity of the results from two widely different species of fish, one would hesitate to accept these singular data. In both the black bullhead and the largemouth black bass there is a decrease in the amount of oxygen which is consumed as the temperature of the water in which they are swimming is raised from twelve degrees to fifteen degrees Centigrade. It seems as if some physiological regulator is called into action as the temperature of the fishes' bodies reaches twelve degrees and continues to act until the body temperature is raised to fifteen degrees. The center of this regulator is probably in the central nervous system, because animals whose central nervous systems have been made insensible do not show this characteristic decrease.

It is interesting to note that in Krogh's monograph on respira-

tion[1] there is only one series of experiments which show determinations of normal fish respiration at these critical temperatures. These are the experiments of Lindstedt[2] and a careful scrutiny of these results show that if the determinations are used as points, a curve similar to those obtained for the black bullhead and the largemouth black bass will result. The curve which Krogh draws through the data does not fit the results.

The presence of this regulator should not be confounding. When one realizes that, all things being equal, the amount of dissolved oxygen in a body of water decreases as the temperature is increased, some sort of regulation in the economy of the oxygen should seem to be almost expected.

The finding that the oxygen consumption of the black bullhead is very low at cold temperatures, while the bass consumes relatively large amounts of oxygen at the same temperatures fits very nicely with our knowledge of the ecology of these two fishes. It may have a practical value in the handling of these fishes.

I should like to express my gratitude to Professor V. E. Shelford, of the University of Illinois, under whose direction these experiments were carried out, and to Dr. D. H. Thompson, of the Illinois Natural History Survey, who was a constant source of help and encouragement during the time of experimentation.

Discussion

DR. WIEBE: The results obtained by Mr. Clausen of the effect of temperature on metabolism are contrary to the results of most workers who have investigated this problem. The observations made by Mr. Clausen to the effect that there is a decrease in the rate of metabolism between 9 and 10 degrees Centigrade, and a rise between 10 and 13 degrees Centigrade and a decrease from 13 to 14.7 degrees Centigrade, are contrary to all physiological principles. According to Vant Hoff's law, there should be a constant increase in the rate of metabolism with an increase in temperature.

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[1]Krogh, August—Monographs on Biochemistry, 1915. London. Pp. 1-170.
[2]Lindstedt, Ph.—Zeitschrift Fur Fischerei, 1914. Vol. 14. Pp. 193-245.

PARASITES OF THE SPOTTED BASS, *MICROPTERUS PSEUDAPLITES* HUBBS, AND SUMMARY OF PARASITES OF SMALLMOUTH AND LARGEMOUTH BLACK BASS FROM OHIO STREAMS

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In 1927 Hubbs described this black bass as a new species and gave distribution records covering eleven states. In 1932 Viosca gave a distribution map with certain modifications and additions to the data already cited. He says, "the range occupies roughly the southeastern quarter of the United States, including the Gulf of Mexico drainage north of Mexico and Florida, east of hundredth meridian and south of the forthieth parallel, and the Atlantic drainage of Georgia. It is absent from the tide level portions of rivers flowing into the Gulf of Mexico and from the sluggish bayou and lake portions of the Mississippi Valley." The distribution in Ohio has been studied by Howland (1932) and by Wickliff and Trautman (1931), who summarized the records to 1931 on a distribution map. The fish in this state are confined to streams tributary to the Ohio River, especially those in the southeastern region.

Wickliff and Trautman say regarding the habitat, "It is commonly found only in the more quiet, silty lowland pools of the stream, in fairly deep water. It is normally not found in the rocky boulder-strewn, upland streams with their faster moving current, which is the home of the smallmouth bass, nor in the quiet weedy bayous and overflow ponds which is the habitat of the largemouth bass. While occasionally all three species can be taken from the same stream, they remain separate to a remarkable degree, each in the kind of water suited to it." There are not many areas in the streams in southern Ohio suitable for the largemouth bass, the smallmouth and spotted bass having a much larger area favorable for their development.

The study of the parasites of the spotted bass is very interesting, to determine if there is any specificity of forms infesting this species as contrasted with related hosts. It is of importance to study their economic damage and their life cycles, especially since it is at present the policy of the Ohio Division of Conservation to propagate this fish in certain hatcheries. The study of the distribution of parasites may aid in determining the native habitat and migration of these fish from certain areas in earlier geological periods. Earlier studies of the parasites of the largemouth and smallmouth bass, (Bangham 1925, 1926), (Hunter and Hunter 1931) report considerable variation in degree of infestation and

in numbers of species when the infection of these host fish from lakes and streams is compared. There is a great difference also in a single large body of water where there are different ecological habitats such as those found in the eastern and western regions of Lake Erie. Data showing such a contrast for black bass taken from these two areas as well as 69 other species of fish from Lake Erie are shortly to be published as a part of the "Studies on Fish Parasites of Lake Erie," Bangham and Hunter.

A summary of the findings of parasites infecting largemouth and smallmouth bass is included. The larger number of the adult smallmouth bass examined were taken from streams in southwestern Ohio. The younger smallmouth and nearly all of the largemouth bass treated in the summary in the table were taken during the summer of 1927 for the Ohio Division of Conservation, as a part of the work of a survey of streams and lakes flowing into Lake Erie. Only the data for stream bass from 60 different locations are included.

Specimens of spotted or Kentucky bass, *Micropterus pseudaplites* which were examined were all obtained from the Ohio Division of Conservation in 1930, 1931 and 1932. All had been collected from streams in southern Ohio by Wickliff, Trautman and Howland. The majority of these fish were examined after having been preserved in a 10 per cent solution of formalin. The data may be incomplete for certain of the ectoparasites. The identification of the members of the trematode family, *Strigeidae,* was rendered difficult and in certain cases impossible due to the lack of living material. The remainder of the specimens of parasites were in such a condition that they could be cleared, stained and mounted for satisfactory study. Of the 140 spotted bass examined, 87 were 10 cm. or less in length and were regarded as young (table), while the remainder which reached a maximum length of 29.5 cm. were grouped as older fish for the consideration of their parasites. Infection was quite high as 90.5 per cent of the adults and 86.2 per cent of the young were found to harbor one or more species, but the degree of parasitism was low in nearly every one of these fish.

Two species of trematodes, *Crepidostomum cornutum* Osborn, and *Bucephalus papillosus* Woodhead, were recovered from the intestinal tract and pyloric caeca of many of the young and adult fish, the first form occurring more frequently in the older fish. Three species of larval trematodes belonging to the family Strigeidae were found encysted in the adult fish: *Neascus ambloplitis* Hughes, from the integument, especially at the base of the fins in black pigmented cysts, in 15.2 per cent; *Neascus van-cleavei* (Agersborg) from liver cysts of 3.8 per cent and one or more unidentified species of *Neascus* from mesentery and liver cysts of 7.5 per cent of these adults. These same forms were found in the young fish in 20.7, 11.5 and 20.7 per

cent, respectively. Experimental studies on *N. ambloplitis* were reported by Hunter and Hunter (1931). Two other species of trematodes, *Clinostomum marginatum* (Rud.) and *Cryptogonimus chyli* Osborn, which have been taken from stream largemouth and smallmouth black bass, were not found in any of the spotted bass. *C. marginatum* was taken from the flesh of infected fish found only in localized areas of certain streams in northern and southwestern Ohio. The life cycle of this form is being studied experimentally by Hunter as a part of the survey work for the New York Conservation Department.

The cestode parasites of the spotted bass are the same as those found in the largemouth and smallmouth bass of streams, but the degree of infestation is different. The three species of cestodes are, *Proteocephalus ambloplitis* (Leidy), *Proteocephalus fluviatilis* Bangham, and *Bothriocephalus claviceps* (Goeze). The first named was found only in the encysted larval stage in both the adult and young and the majority were recovered from the latter. This form is rarely found in stream bass, but it is a very serious handicap to growth and reproduction of lake bass, (Bangham 1928 and Hunter and Hunter 1931).

The larval stages were found as characteristic mesentery cysts in 35.6 per cent of the young spotted bass. This is a high percentage of infestation even for lake fish. The only smallmouth and largemouth bass carrying this infestation were taken near the outlets of lakes where the fish were infested with larval and adult stages of this cestode. The source of the infestation of the younger spotted bass may have been from adults of largemouth or smallmouth bass planted in the streams from Lake Erie or certain adults of the spotted bass may carry mature *P. ambloplitis* even though no infested individuals have been found. Their peculiar habitat may be such that the first intermediate hosts are able to live although the cycle is not usually established under stream conditions. Hunter and Hunter (1929) report experiments in which they have infected the following species of copepods with eggs of *P. ambloplitis*: *Cyclops vulgaris, Cyclops prasinus, Eucyclops agilis, Macrocyclops annulicornis*. By examination of the stomach contents two additional forms, *Hyalella knickerbockeri* and *Cyclops leucharti* were found to act as first intermediate hosts, (Bangham 1928). The latter species had not been identified when the paper cited was published.

It would be interesting to make a study of the copepod population of the areas of streams where the spotted bass are found and compare this with the copepods of other stream areas. That the first intermediate hosts are not established in the stream areas where the largemouth and smallmouth bass spawn seems a probable explanation of the lack of this infestation in streams, as bass from Lake Erie have been planted in Ohio streams since 1883 (Bangham, 1928b).

Proteocephalus fluviatilis was found in both the adult and young of the spotted bass but the infestation is not as heavy as found in stream smallmouth bass. This cestode has not been found in bass from lakes. The larva of this form is not encysted in the fish host, but develops from the early larval stage to maturity in the intestine when it enters the fish from the copepod. The other cestode, *Bothriocephalus claviceps,* was secured from adult and young spotted bass in four and nine instances, respectively. It is occasionally found in the intestinal tract of largemouth and smallmouth black bass from both lakes and streams.

Acanthocephala were but rarely encountered in the spotted bass. *Leptorhynchoides thecatus* (Linton) was taken in two adults and two young. This same species was found in stream smallmouth and largemouth bass and to a much larger degree in these fish from lakes. Another species, *Neoechinorhynchus cylindratus* (Van Cleave), was present in these latter species of bass from both streams and lakes, but here also much more abundant in fish from the latter habitat. Both of these species encyst in the body cavity if taken in an underdeveloped stage from the first intermediate host.

The largest of the nematodes in the spotted bass, *Raphidascaris brachyurus* (Ward and Magath), was taken from 20 per cent of the adults. This same form was recovered from 40 per cent of the adult smallmouth bass from streams in southwestern Ohio. It was very rarely taken from smallmouth bass from streams in northern Ohio or from Lake Erie. When Ward and Magath (1916) decribed the species, their only material consisted of male specimens from the stomach of black bass taken at Lake St. Clair, Michigan. On the basis of female specimens and a larger number of individuals their description will be added to elsewhere.

A smaller species of nematode, *Spinitectus carolini* Holl is somewhat more numerous in the intestinal tracts of the spotted bass. This species was recently redescribed by Mueller and Van Cleave (1932). This same worm has been taken from smallmouth and largemouth bass from many regions in Ohio. A larval nematode, *Camallanus* sp., was obtained from the intestinal tracts of three and nine adult and young spotted bass, respectively. This is probably *C. oxycephalus* Ward and Magath, as this larva resembles that species recovered from smallmouth and largemouth bass from streams. Unidentified larval nematodes were taken from mesentery cysts and free in the intestine in certain of the spotted bass. Certain of these larval forms appeared to be young of *R. brachyurus*.

Parasitic copepods while not often found in large numbers, were taken from the gills of many spotted bass. Three species, *Ergasilus caeruleus* Wilson, *Ergasilus centrarchidarum* Wright, and *Achtheres micropteri* Wright were taken from adult spotted bass in 45.3, 13.2 and 3.8 per cent, respectively, while the young carried but 7.5 per cent of the first named form on their gills. Each of these copepods

were also taken from the gills of small numbers of smallmouth bass from streams. Stream largemouth bass carried only E. *centrarchidarum.*

This completes the list of parasites infesting the spotted bass, but a more extensive study of fresh fish of this species would probably yield other forms. A study of the table shows a marked similarity of the infestation of these three species of black bass from streams. There is a more marked difference between the parasites of the smallmouth and largemouth bass than between those of the spotted and smallmouth bass. This similarity of infection in the smallmouth and spotted bass is in harmony with their classification in one genus *(Micropterus),* distinct from the genus *Aplites,* now recognized for the largemouth bass. An explanation for the more marked infestation of *P. amblopltitis* in the spotted bass has already been given in the possibility of the habitat of this fish furnishing a more suitable location for the development of the host of the first larval stage. The more marked degree of infestation of the spotted bass with gill copepods may be due to localized conditions.

A check list for parasites of the black bass from inland lakes in Ohio and Lake Erie follows. This includes parasites from 179 smallmouth bass with an infestation of 89.5 per cent and 275 largemouth bass with an infestation of 86.4 per cent. In nearly every case the degree of infestation is heavier for these black bass from lakes. Complete data covering the lake forms will be published elsewhere.

Check List of Parasites of Smallmouth Black Bass from Lakes in Ohio and Lake Erie

Trematoda:

Crepidostomum cornutum (Osborn), *Cryptogonimus chyli* Osborn, *Leuceruthrus micropteri* Marshall, *Ancyrocephalus* sp., *Clinostomum marginatum* (Rud.), *Microphallus opacus* Ward, *Allacanthochasmus varius* Van Cleave, *Azygia longa* Leidy, *Bucephalus papillosus* Woodhead, *Neascus van-cleavei* (Agersborg), *Neascus* sp., *Paramphostomum stunkardi* Holl.

Cestoda:

Bothriocephalus claviceps (Goeze), *Proteocephalus pearsei* La Rue, *Proteocephalus osburni* Bangham, *Proteocephalus ambloplitis* (Leidy), *Triaenophorus cooperi* Hunter and Bangham.

Nematoda:

Camallanus oxycephalus Ward and Magath, *Spinitectus carolini* Holl, *Agamonema* sp., *Dacnitoides cotylophora* Ward and Magath.

Acanthocephala:

Leptorhynchoides thecatus (Linton), *Neoechinorhynchus cylindratus* (Van Cleave).

Copepoda:

Ergasilus centrarchidarum Wright, *Ergasilus caeruleus* Wilson, *Achtheres micropteri* Wright, *Lernaea* sp.

Protozoa:

Myxobolus sp., *Cyclochaeta domerguei* Wallengren, *Ichthyophthirius multifiliis* Fouquet.

Leech:

Piscicola punctata (Verrill).

Fungus:

Saprolegnia parasitica Coker.

Check List of Parasites of Largemouth Black Bass from Lakes in Ohio and Lake Erie

Trematoda:

C. cornutum, C. chyli, L. micropteri, Ancyrocephalus sp., *Neascus amblopliti*s Hughes, *N. van-cleavei, P. stunkardi.*

Cestoda:

P. pearsei, P. ambloplitis.

Nematoda:

Dictophyme sp., *C. oxycephalus, S. carolini, D. cotylophora Agamonema* sp., *R. brachyurus.*

Acanthocephala:

L. thecatus, N. cylindratus.

Copepoda:

E. centrarchidarum, E. caeruleus, A. micropteri.

Protozoa:

Myxobolus sp., *C. domerguei, I. multifiliis, Chilodon cyprini* Moroff.

Leech:

Placoldella montifera Moore.

Fungus:

S. parasitica.

SUMMARY OF PARASITES OF BLACK BASS FROM OHIO STREAMS

Hosts		Spotted black bass—adults *Micropterus pseudaplites* Hubbs		Young spotted bass		Smallmouth bass *Micropterus dolomieu* (Lacepede)		Largemouth bass *Aplites salmoides* (Lacepede)	
Number examined		53		87		115		33	
Number infested		48		75		100		21	
Percentage infested		90.5		86.2		87		63.3	
Trematoda:									
Neascus	N	4	4	8	10	4		5	2
ambloplitis	D	*	**	*	**	*		*	**
Hughes	L	F	F	F	F	F		F	F
Neascus	N	2		10		11	20		
van-cleavei	D	*		*		*	**		
(Agersborg)	L	L		L		L, M	L		
Neascus	N	4		18		5		3	
Sp.	D	*		*		*		*	
	L	M		M		M		M	
Clinostomum	N					5	8	2	
marginatum	D					*	**	*	
(Rud.)	L					F	F	F	
Cryptogonimus	N					4		1	
chyli	D					*		*	
Osborn	L					DI		DI	
Crepidostomum	N	10	2	7	2	10	2	1	
cornutum	D	*	**	*	**	*	**	*	
(Osborn)	L	DI	DI	DI	DI	DI	DI	DI	
Bucephalus	N	10	2	15	10	13		2	
papillosus	D	*	**	*	**	X		X	
Woodhead	L	DI	DI	DI	DI	DI		DI	

Hosts		Spotted black bass—adults *Micropterus pseudaplites* Hubbs		Young spotted bass			Smallmouth bass *Micropterus dolomieu* (Lacepede)					Largemouth bass *Aplites salmoides* (Lacepede)	
Cestoda:													
Proteocephalus	N	1†		19†		12†	2†					1	
ambloplitis	D	*		*		**	*					*	
(Leidy)	L	M		M		M	L, M					L	
Proteocephalus	N	2	7†	3	15†	4†	20	4	25†	20†	24†	1	4†
fluviatilis	D	*	**	*	*	**	*	**	*	**	***	*	**
Bangham	L	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di	Di
Bothriocephalus	N	1	3†	3		6†		1					
claviceps	D	*	*	*		*		*					
(Goeze)	L	Di	Di	Di		Di		Di					
Acanthocephala:													
Leptorhynchoides	N	2		2				4		1		8	
thecatus	D	*		*				*		**		*	
(Linton)	L	Di		Di				Di		Di		Di	
Neoechinorhynchus	N							2				10	
cylindratus	D							*				*	
(Van Cleave)	L							Di				Di	
Nematoda:													
Agamonema	N	11		3		4		3				2	
Sp.	D	*		*		*		*				*	
	L	Di, M		Di		M		M				M	
Camallanus	N	3†		9†				2				1	
Sp.	D	*		*				*				*	
	L	Di		Di				Di				Di	
Spinitectus	N	8	4	5				8				1	
carolini	D	*	**	*				*				*	
Holl	L	Di	Di	Di				Di				Di	
Raphidascaris	N	8	3†	4				8					
brachyurus	D	*	*	*				*					
(Ward and Magath)	L	Di	Di	Di				Di					
Copepoda:													
Ergasilus centrarchidarum	N	20	4	4				5				2	
	D	*	**	*				*				*	
Wright	L	G	G	G				G				G	
Ergasilus	N	7						2					
caeruleus	D	*						*					
Wilson	L	G						G					
Actheres	N	2						1					
micropteri	D	*						*					
Wright	L	G						G					
Protozoa:													
Sporozoa	N							2				3	
encysted	D							*				**	
	L							G				G	
Hirudinea:													
Piscicola	N							1				1	
punctata	D							*				*	
Verrill)	L							E				E	

N—Number infested.
D—Degree of infestation.
L—Location in host.
M—Mesenteries.
G—Gills.
E—Exterior.
Di—Digestive system, interior.
L—Liver.
***—1-9 parasites of species named.**
****—10-49 parasites of species named.**
*****—50 up parasites of species named.**
†—Larval.

BIBLIOGRAPHY

Bangham, R. V.

1925—A study of the parasites of the black bass in Ohio, with special reference to their life history and distribution. Ohio Jour. Sci., 25: 255-270.

1926—Parasites other than cestodes in black bass of Ohio. Ibid. 26: 117-127.

1928a–Life history of bass cestode, *Proteocephalus ambloplitis,* Trans. Am. Fish. Soc. 1927: 206-208.

1928b–Parasites of black bass. Sc. Month. 27: 267-270.

Howland, J. W.

1932—Studies on the Kentucky black bass. Trans. Am. Fish. Soc. 1931: 89-94.

1932—The spotted or Kentucky black bass in Ohio. Bull. Ohio Dept. Agr., Div. Conserv. Vol. 1, No. 4. 19pp.

Hubbs, Carl L.

1927—*Micropterus pseudaplites,* a new species of black bass. Occas. Papers Mus. Zool. Univ. Mich. 184: 1-15.

1932—The species of black bass. Trans. Am. Fish. Soc., 1931: 86-88.

Hughes, R. C.

1927—Studies on the trematode family Strigeidae (Holostomidae) No. VI. A new metacercia *Neascus ambloplitis* sp. nov., representing a new larval group. Trans. Am. Mic. Soc. 46: 248-268.

1928—Studies on the trematode family Strigeidae (Holostomidae) No. IX. *Neascus van-cleavei* (Agersborg) Ibid. 47: 320-341.

Hunter, G. W. III and Hunter, Wanda S.

1929—Further experimental studies on the bass tapeworm, *Proteocephalus ambloplitis* (Leidy). Biol. Surv. Erie-Niagara Syst. 18th Ann. Rpt. N. Y. Conserv. Dept. 1928: 198-207.

1931—Studies on fish parasites in the St. Lawrence Watershed. Ibid. 20th Ann. Rpt. 1930: 197-216.

Mueller, Justis F. and Van Cleave, H. J.

1932—Parasites of Oneida Lake fishes, Part II. Roosevelt Wild Life Bull. 3:79-148.

Viosca, Percy

1932—The southern small-mouth black bass. Trans. Am. Fish. Soc. 1931:95-98.

Ward, H. B. and Magath, T. B.

1916—Notes on some nematodes from fresh-water fishes. Jour. Parasitol. 3:57-63.

Wickliff, E. L. and Trautman, M. B.

1931—Some food and game fishes of Ohio. Bull. Ohio Dept. Agr. Div. of Conserv. No. 7:1-39.

Yorke, W. and Maplestone, P. A.

1926—The nematode parasites of vertebrates. Blakiston, Phila., Pa.

Discussion

Dr. Juday: I should like to inquire whether Dr. Bangham found this Protocephalus ambloplitis had sterilized the black bass.

Dr. Bangham: We have found in Ohio, tapeworms in the larval stage, but they are found almost exclusively in the lake bass. We have found it as a mesentery cyst in the stream bass, probably due to a peculiar habit or condition of spotted bass that is not encountered in other forms of stream bass. But it is almost exclusively a lake form. A good many hatcheries get their fish from streams for that reason, or rear their own fish.

Dr. Juday: I should like to know whether Dr. Bangham has observed any correlation between the degree of parasitism and the rate of growth. That is a problem which has come up with us—the difference between the rate of growth of those heavily parasitized and those that are lightly parasitized.

Dr. Bangham: That is true—we have not as yet done anything to take any definite records, but I plan to do it, especially for hatchery fish.

The President: The next is a paper by J. Clark Salyer on "Predator Studies in Michigan Waters."

Dr. Greeley: Mr. Salyer could not be present, and he has asked me to present his paper. Mr. Salyer has been working for two seasons on predator investigations, particularly in relation to the sports fisheries, on inland streams and lakes. His principal investigation has been in the study of stomach contents and actual field studies of the number of various fish eating mammals and birds, snakes and so forth, and as yet he is not ready to report on that particular investigation. This paper deals with an investigation of the probable causes of death of fish which have been found dead in streams, thus making interesting correlations with his stomach examination work. His material is gathered not only incidentally and by various investigators around the state who had picked up these fish dead, but also—and the majority of it was obtained in this way—by cooperative work with the hatchery superintendents in the rearing stations. A good number of dead fish which are representative of wild conditions were picked up on streams on which rearing stations are built.

PREDATOR STUDIES IN MICHIGAN WATERS

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Studies of fish predators, with particular reference to those affecting inland lake and stream habitats, have been in progress by the Institute for Fisheries Research since 1930. The methods of study have included stomach examinations, field work to determine predator abundance in relation to fish abundance, and examination of fish found dead in wild waters. The present report is based only upon studies of dead fish received during 1931 and 1932. Most of the specimens were fish which were picked up dead on head screens of trout-rearing stations, of the Michigan Department of Conservation. The head screens at these stations make effective barriers which catch any dead fish which the stream carries down. Since the screens are frequently cleaned by the caretakers the fish are usually found soon after lodging against the barriers. Directions for preserving and labelling the specimens were distributed to caretakers at the beginning of the 1931 field season and large numbers of dead fish have been saved for study each season. Miscellaneous dead trout specimens picked up on several streams by field investigators of the Institute for Fisheries Research during 1931 and 1932 are included in the material upon which the present report is based.

Most of the fish received were in surprisingly good condition. The color of most was bright, the flesh was firm, and the peritoneum was normally pigmented. In the majority of cases the trout were fat and had full stomachs, showing that they had died rather suddenly. The absence of crayfish marks on all but one or two specimens demonstrates the dispatch with which the fish were carried down to the head screens by the current. Crayfish marks are a sure sign of delay in the floating down of the fish to the head screens. Crayfish remove from the stream in 24 hours most dead fish touching the bottom or checked and lodged in backwaters, even trout up to 14 inches in length. These facts were determined in the course of field work on fish predators during 1931 and 1932. The activity of crayfish in consuming dead trout limits to some degree the number of fish which will be carried down to the head screen. In spite of this fact, an adequate number of specimens for this preliminary study was secured from head screens.

The writer is convinced that the cause of death in the fish thus obtained is a valuable aid in estimating the relative severity of predator pressure on the trout streams in comparison with other forms of destruction. The careful recovery, preservation, and label-

ling of fish from screens will in the course of several seasons yield valuable data as to the degree of predator activity on natural streams, information which stomach analysis will not always yield. The date, time of day, and any unusual facts, as a run of hot weather, are valuable data to include. The fish were preserved in a solution of one part formalin to ten parts water.

Means of Identifying Cause of Death

The predators leave a characteristic mark on the fish whereby they can be identified by the experienced worker. Snakes leave a series of punctures grouped in definite vertical lines at right angles to the long axis of the fish's body. These are made in manouvering the fish so as to swallow it head first. The point of seizure is generally apparent also, from rather deep creases and abrasions in that region. The vertical rows of punctures are overlain by a horizontal series of fine striae left by the teeth of the dentigerous bones when the swallowing process is initiated. It is apparent from some of the specimens that trout frequently escape the water snake in the early stages of the swallowing act, and are then subsequently overcome by the onset of fungus. I have not seen a case of recovery from snake wounds, although recoveries from injuries caused by birds and lampreys are rather frequent.

Turtles, especially the larger ones, make large triangular gashes in the body of the fish. A turtle bite is generally fatal. Several small trout among the specimens reported upon evidently had their caudal fins amputated by these agents. A large lamprey (*Ichthyomyzon concolor*) received from one station, had the posterior half of its body severed by a clean-cut turtle's bite.

Bird marks are the most characteristic of all. It is possible to identify the species of bird concerned. The Great Blue Heron can deliver a death-giving thrust with its pointed, closed bill; or slightly opening the bill, can pick up a fish as with a pair of forceps. The fact that the edges of the rami of the bill are somewhat serrated, makes the last-mentioned act more certain. It is untrue that Herons always spear their fish. Most trout up to 7 inches in length in shallow water are taken by the forcep-like action of the bill, which with its halves somewhat opened is driven by the force of the blow well down into and over the sides of the fish. In deeper water, the fish if from 6 to 15 inches in length is always speared. The Great Blue always strikes at the point of the dorsal fin. Rarely in larger fish, 17 to 19 inches, the thrust is given through the back of the head. If the blow is true, the back of the fish is broken. If the blow is not fully centered the result is equally fatal, the side of the fish being gouged out and often the viscera revealed. Those fish that escape the Heron fall certain prey to fungus from their wounds. A Heron rarely misses a medium or large-sized fish. It

is the smaller fish which most often exhibit healed marks. The stroke of a Great Blue Heron's bill is delivered with such speed as to be fully comparable with the rapidity of the strike of a poisonous reptile or the tongue movements in certain amphibians. After striking the fish, the sharp edges of the bill leave a clean cut pair of converging marks or lines on each side of the fish's body when it is picked up and further manipulated for swallowing. The size of these marks makes them distinctive from the smaller ones left by the American Bittern or by the Green Heron.

The Bittern, commonly called shikepoke or marsh-pump by hatchery men, more frequently spears its fish, often making several neat, rounded punctures deep into the body. The thrusts are made anywhere in the anterior dorsal region from the head to the dorsal fin. Characteristic beak marks are also made in handling fish preparatory to swallowing.

The Belted Kingfisher rarely, if ever, spears its fish. The prey is captured by a forcep-like action of the moderately serrated bill, the force of the down-plunging bird wedging the fish securely in the slightly opened mandibles. The fish is almost invariably seized in the nape region. Due to the Kingfisher's habit of moving the fish backward or forward in the mandibles to balance it while flying or in its efforts to swallow a fish much larger than is possible, the region of the fish between the head and dorsal fin is severely champed and marked with an intricate pattern of fine lines left by the sharp edges of the mandibles. This pattern is a positive clue to the Kingfisher when trout 6 to 8 inches are picked up in the field thus marked, for this bird frequently catches larger fish than it is able to swallow. It is rare for a Kingfisher to swallow a fish longer than 4 inches, although some 5 inches long are managed. The larger fish, although frequently caught, are either dropped by the bird while flying or through its inability to swallow a fish of such size. It is not uncommon to see Kingfishers fly about a stretch of stream for several minutes with a 5 to 8 inch fish only to lose it finally. A Kingfisher suddenly startled will usually drop a fish too large to be immediately swallowed. The same is true when the bird is fired on with a shot-gun, even if the bird is missed.

The peculiarities and marks of fish-eating birds described above have been adequately checked by field observations and the examinations of hundreds of fish from the stomachs of such birds in the course of the writer's study on fish predators.

Mink leave the mark of their characteristic dentition on the side of the fish caught. This is a horseshoe-shaped pattern of punctures.

Lamprey marks appear as round or oval spaces of bare skin on the trout which, if examined closely, show a slightly pitted surface. This applies to healed wounds. The raw or fresh lamprey mark

is unmistakable. When healed it is interesting to note that the scar is devoid of scales and has lost its ability to secrete the protective mucus. This last statement is true also of healed birds marks which appear as long sears or welts on the side of the fish. How much the loss of the secretory function of these areas is a factor in the ultimate survival of the fish is conjectural, although some mucus invades the denuded area from contiguous, healthy areas. It is significant that many of the fungused trout in this material had bird and lamprey marks in various stages of recovery.

It will be seen that predators are responsible for a large proportion of the fish found dead in streams, after we exclude the heavy mortality due to streams drying up or becoming overly warm, in such years as 1930 and 1931. The number of fish definitely killed by fish-eating birds exceeds all other predator destruction and may be significant (see summary table).

It is regrettable that more cannot be learned of the part disease, aside from predators, plays in the death of head screen fish. In the case of a bacterial disease, the manner of preservation and the time which must elapse between death and finding of the fish, militates against determining the specific organism at work. Still lesions and suppurating surfaces are apparent, as are fungus and ectoparasites, when examined with the aid of a microscope. On the evidence supplied by this report it will be seen that diseases usually play a minor part in causing the death of the fishes which were studied.

Traumatic injuries are evident in a handful of specimens; at the manner of their happening we can only guess. An astonishing number of trout were badly hooked and seemingly died from their injuries. Despite previously described injuries many of the fish died from causes not detectable. They were in good color, fat, with full stomachs, and had no evident injuries.

A total of 153 fish were received by the Institute, of which 119 were trout and 34 were non-game fish.

Each specimen was measured, examined carefully inside and outside for injuries or disease, and examined with a microscope for ectoparasites. The causes of death in these fish are discussed under the following heads.

Deaths Due to Each Agency

1. *Fish-eating birds*

This group of predators accounted for 32 trout ranging in size from 2½ to 19 inches. Six other fish were also killed by them. Listed as to species the kill is as follows:

Kingfisher: 17 trout, 1 brook lamprey, 1 common sucker, 1 mud minnow.

Great Blue Heron: 11 trout, 2 muddlers (1 *Cottus cognatus,* 1 *Cottus bairdii*).

Bittern: 4 trout, 1 common sucker.

Green Heron: No trout, 1 yellow perch.

All of these fish had wounds severe enough to have caused the death of each. A few bore bird marks from which they had recovered. Further, it should be remembered that all of these birds disdain dead fish. I have been unable to find the slightest trace of their utilization of fish offal in any instance.

2. *Mink*

One of the fish found dead had clearly been killed by a mink.

3. *Lampreys*

Lampreys were the initial cause of death of 2 trout and of 2 ling or burbots, the abrasions made by these parasites becoming secondarily fungused. A number of the fish concerned in this report show old lamprey scars from which the fish recovered only to subsequently fall a victim to another predator or disease. At the Sturgeon River station an eleven inch rainbow caught by a fisherman in the main stream was turned over to the station man. This fish had had the whole top of the head eroded by lampreys but was healed at the time of capture, was fat and in perfect condition. There was no reason why it should not have been used for food. It might be well to state to the fishing public that fishes bearing healed lamprey or bird scars are perfectly palatable if nothing else appears to be wrong with them.

4. *Diseases*

The role played by disease in the death of these fish can best be understood by reading the cases of the individual fish listed at the end of this report. Twenty trout, 17 long-nose dace, and 1 black-nose dace belong to this group. Some 4 or 5 cases listed in this group doubtless originated from slight abrasions becoming subsequently heavily fungused and spreading over the whole fish.

A heavy infestation of gill lice *(Salmonicola edwardsii)* was found in six instances in the trout of this group. In four instances out of six, the hatchery attendant mentions a high water temperature for the day on which they were picked up. It is probable that numbers of gill lice interfere with the mechanics of respiration to such an extent that on an abnormally hot day, the fish so infested succumb because of the added physiological strain. At least we have here a good correlation with the two facts. The case of a 10 inch wild brook trout sent in from the Sturgeon River station is full of interest in this connection. This fish got into one of the rearing ponds where it lived for several days, finally dying on a day when the water temperature reached 81 degrees F. There were 43 adult gill lice on the gills of this trout. Its nose was some-

what abraded and there was a recovery-mark of an old lamprey laceration on the caudal peduncle.

A number of the dead trout found in the streams had presumably been killed by the dread disease known as *Furunculosis*. This hatchery-spread disease is likely to become increasingly serious, in the opinion of the Institute.

The significant loss of trout in streams due to disease confirms the current policy of the Michigan Fish Division in not dumping badly diseased trout into the stream, just to save them. This loss due to disease also stresses the importance of further investigation of trout diseases, in hatcheries as well as in nature.

5. *Snakes*

Snake marks were definitely observable on 3 trout and on 4 muddlers (3 *Cottus cognatus* and 1 *C. bairdii*). The onset of fungus completed the work of destruction.

6. *Turtles*

Turtles snapped the caudal fins from 2 trout sent in, and may be responsible for the peculiar injuries listed under the heading of traumatic injuries. A large silver lamprey *(Ichthyomyzon concolor)* sent in from the Bear Creek station had the posterior half of its body severed by a turtle bite. While examining the Pere Marquette River on July 14, 1931, Dr. Greeley of the Institute for Fisheries Research captured a 21½ pound snapping turtle which had just caught a 17 inch (estimated) brown trout. The trout was fresh and firm and the probability of its being caught by the turtle was strengthened by finding the bones and flesh of a 9 inch brown in this turtle's intestine when the stomach and intestines were analyzed. Dr. Greeley states that the habit of the brown trout in taking refuge under stones and in crevices when disturbed would seem to make it a ready prey for the snapper which regularly investigates such places. Once seized by the snapper's powerful jaws, a trout has little chance to escape alive, even if it should struggle free from the grasp of the snapper.

7. *Nutrition*

Two of the trout were of the type known as "racers" by hatchery men. They were slender, had a compressed head large in proportion to body size, and had empty stomachs with no store of fat.

8. *Hooked fish*

The 19 trout in this group had either the mouth parts or opercular apparatus badly torn, showing plainly the effects of having been hooked. No natural predator would leave similar lacerations. Many were hooked exterior to the mouth parts in the opercular region. One muddler *(C. bairdii)* had the lower part of mouth and jaw torn out,

probably by a baited hook. It is significant that many of the hook-torn trout are just under legal size. From the mutilation of some, it is apparent that they were flipped off the hook by lazy fishermen without resorting to the use of the hands, or that the hook was otherwise forcibly jerked out.

9. *Dynamite*

One trout was almost certainly and four others were probably killed by dynamite.

10. *Traumatic injuries*

The name is applied to one type of injury for want of a better term. The three trout included here had the snout portion of the head cut off smoothly and vertically as if it had been done with a knife. Turtles might be responsible, but it is doubtful if they would leave such a clean-cut wound.

11. *Unknown causes*

Twenty trout fall in this group. Examination failed to give any clue to their death. For the most part, they had good color, were unmarked and had food in their stomachs. The high water temperatures recorded at some of the stations may have been a causative factor.

It is well known that many thousands of trout were killed in Michigan during the dry years of 1930 and 1931, especially in the Upper Peninsula. The thousands of small fingerling rainbow trout which were washed against the head screen of the Sturgeon River Rearing Station in Cheboygen County were presumably killed by high temperature.

No doubt many trout are killed in nature by unfavorable environmental conditions. Thus the death of trout and other fishes in the headwaters and the new Hardy Dam, on the Muskegon River in Mecosta county, was probably rightly attributed to the fouling of the water by decomposing vegetable matter. Probably some of the 20 trout of our sample which died of unknown cause, were killed by some bad chemical condition.

It must be emphasized that the figures just given, and summarized in the table do not represent the destruction ratios between the various agents which kill fish in our streams. They refer only to the cause of death of fishes found dead in streams. The actual ratio among predators can only be found by exhaustive stomach analysis. The material for such examinations are being collected from a wide range of stream localities over the state. This latter phase of predator investigation has been intensively followed by the writer in 1931-1932. The present report is merely a corollary of the main line of research.

Cause of Trout Deaths, Expressed as Per Cent of Sample Killed by Each Lethal Agent

Figures refer only to fish *found dead* in streams

All predators combined, 33 per cent.
- Bird predators, 27 per cent (Kingfisher, 14 per cent; Great Blue Heron, 9 per cent; Bittern, 3 per cent).
- Snake predators, 3 per cent (water snake presumably; bites followed by fungus).
- Turtle predators, 2 per cent (snapping turtle in part at least).
- Lamprey predators, 1 per cent (silvery lamprey only).
- Mammal predators, 1 per cent (mink).

Cause unknown (probably high temperatures in large part), 25 per cent. See also note in subtitle to table.

Human agencies, 21 per cent (hooking, 17 per cent; dynamiting, 4 per cent). *Note:* dynamite proportion doubtless too high, owing to fact that Conservation Officers sent in samples from streams where dynamiting was suspected.

Diseases, 17 per cent. Including bacterial diseases (*Furunculosis,* etc.), fungus diseases and parasite diseases (gill louse, etc.).

Malnutrition, 2 per cent.

Traumatic injuries, 3 per cent (head sheared off clean).

SUMMARY TABLE OF PROBABLE CAUSES OF DEATH OF FISH IN MICHIGAN TROUT STREAMS

Based on dead fish caught on head screens of rearing stations and dead trout picked up in streams. Not including several thousand small rainbow trout fingerlings found dead on the head screen of the Sturgeon River station 1931, during a very hot period.

	Fish killed												
PREDATORS	Brook trout	Brown trout	Rainbow trout	Perch	Ling	Common sucker	Mud minnow	Long-nose dace	Short-nose dace	Muddler (*cognatus*)	Muddler (*bairdii*)	Silver Lamprey	Brook Lamprey
Kingfisher	12	4	1			1	1						1
Gt. Blue Heron	4	5	2							1	1		
Bittern	3		1			1							
Green Heron				1									
Mink	1												
Lamprey		1			2								
Disease	20							17	1				
(Snake followed by fungus)	3									3	1		
Turtle	2											1	
Nutrition	2												
Hooking	19	1								1			
Dynamite	3	2											
Traumatic injuries	3												
Unknown (hot wat. in part)	30									1			
Totals	102	13	4	1	2	2	1	17	1	6	2	1	1

Grand Total—119 trout plus 34 other fish equals 153 fish.

Discussion

Dr. Hubbs: I might mention that this paper is presented here merely as a suggested report; the amount of data included in it is entirely insufficient for final analysis of this problem. It is rather a new line of attack on the problem of what kills the fish in the streams, and it is something which should be followed further. We have presented it primarily for the purpose of suggesting this method in case others may wish to follow it through also. The report was written before Mr. Salyer left our work in Michigan about two years ago, and since that time we have acquired a considerable amount of new material along this line, and a much larger amount will be gathered in the future so that the work can be carried further. Mr. Salyer, I might say for the information of those present, has now returned to Michigan and is investigating the problem of the relation of beaver to trout for the Department of Conservation—one of our most extensively argued questions.

Mr. Hogan: We shot a crane on one of our rearing ponds two years ago, and we removed from the stomach of the crane about 125 small bass which were about three-quarters of an inch long, two golden shiners about three inches long, and one crawfish. Besides that, he is protected.

Mr. Grim (Pennsylvania): Does anyone know whether the turtle will catch a large fish?

Dr. Hubbs: There is no question about it; I have seen them do it, and I know it does occur. Just what percentage of the food of the turtle is made up of fish is another problem. Mr. Salyer is including these animals in his further studies of predators. Turtles certainly are capable of catching fish, and most species of turtle do eat fish; as to the percentage that will have to be determined by a continuation of the studies.

Mr. Grim: I caught two snappers this summer; one of them weighed thirty-eight pounds, and I am going to weigh the other one, because my scales would only take forty pounds—it was between forty and fifty pounds. I kept these turtles in a pond with two trout for three weeks; I saw the trout fanning these turtles' noses with their tails, and the trout stayed there for three weeks unharmed. It is just a question whether the turtle will catch the large fish.

Dr. Hubbs: We ran the same sort of experiment with a considerable number of species of turtles, and every species we tried was found to clean out the fish in short order—all except one snapping turtle; the snapping turtle refused to touch the fish. The snapping turtle is adept at catching prey; our boys in the lakes have seen them catch ducks. The nature of the food in their stomachs indicates conclusively they will catch fish in some degree.

Mr. Cobb (Connecticut): Reference has been made to fish having been killed after being hooked. Under normal conditions such as exist around parts of June and July, after a fish has been hooked and played and then released as carefully as the average man would release him, what would be the average chance of that fish—I am referring to trout—coming through without injury?

Dr. Harkness: Mr. White, working for the Biological Board in New Brunswick, carried out a series of experiments on that problem. After cutting the gill arches of the trout just as they might be torn by a hook, he got a relatively high percentage of recoveries—I think it was 80 per cent. That is published somewhere in the Transactions of the Biological Board of Canada —I am not certain whether in a progress report or in the regular Transactions, but it could be obtained by writing to Dr. H. E. Huntsman at the University of Toronto, or at St. Andrews, New Brunswick.

Mr. Cobb: May I ask whether the temperatures were taken in each case?

Dr. Harkness: Of course the temperatures of the waters in which the experiments were carried out would be recorded, but I do not know the details of the experiments. I only know the experiments were conducted, and that was the result. You would have to get the details from the published report.

Mr. Cook (Michigan): At one of the hatcheries in Michigan we have conducted some investigations along that line. For control we used a seine and took fish just under the legal size in one of several ponds, releasing them with as much care as possible, figuring that that would be a fair control over the others. Then we caught one hundred fish by one means or another, using barbed and barbless hooks and flies—dry fly, wet fly and bait, in fact all the different methods that were employed in Michigan—and placed these fish in the various ponds. The following table indicates the result for 1930 and 1932:

1930	No. of fish used	Loss	% of loss
Pond No. 1—Caught with artificial fly, No. 12 barbed hook, September 17th	200	5	2½
Pond No. 2—Caught with No. 5 Sproat barbed hook, natural bait, September 19-20	200	21	10½
Pond No. 3—Caught with No. 6 Sproat barbless natural bait, September 19-20	200	19	9½
Pond No. 4—Caught with seine, September 20	200	...	
Total loss and percentage based on 600 fish caught with hook and line	....	45	7½
1932			
Pond No. 1—Caught with artificial fly, No. 10 barbed hook, September 15th	200	6	3
Pond No. 2—Caught with barbed hook, natural bait, September 14	200	14	7
Pond No. 3—Caught with barbless hook, natural bait, September 15	200	7	3½
Pond No. 4—Caught with barbless hook, natural bait, September 21	100	2	1
Total loss and percentage	...	29	4 1-7

NOTE: Fish used in 1930 averaged from five to seven inches in length. Practically all losses occurred within twenty-four hours. Experiment was terminated on October 31st, 1930. Fish caught with seine used as a control.

NOTE: Fish used in 1932 ran from three and one-half to seven inches in length, experiment continued thirty days. As in the preceding experiment, the major part of the losses occurred during the first twenty-four hours after hooking.

It is surprising to note that the dry and wet fly made much the best showing, the greater loss, as may be seen from the figures, being among the fish caught with bait. These fish were not caught a second time; in fact they were not subjected to what we would call ordinary stream con-

ditions. So this year the man working on that has changed his system somewhat; we are catching these fish over again at intervals of about a week, or as soon after they were taken the first time as they would take the fly the second time—sometimes subjecting the ponds to fishing almost continuously—to get some correlation, if possible, with what would be actual stream conditions where the fish are subjected to continuous pounding, you might say, day after day. We hope to be able to present something in this connection to the Society next year, bearing upon the results of the two years' investigation; we felt that the findings were too much of a preliminary character to warrant their presentation this year.

SALIENT PROBLEMS IN THE ARTIFICIAL REARING OF SALMONOID FISHES, WITH SPECIAL REFERENCE TO INTESTINAL FUNGISITOSIS AND THE CAUSE OF WHITE-SPOT DISEASE

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I. Introduction

Fundamentally, the purpose of the artificial propagation of fish is two-fold: (1) To rear to the adult state all potential fish represented by the eggs or young deposited. (2) To rear or breed only individuals that are most productive, and viable and that can be produced most economically.

Under the first rubric, in order to accomplish the purpose, it would be necessary to eliminate all the enemies the young would encounter in nature from the egg to the adult state. Enemies to the young fish, for example, are not only larger fish of the same species but birds, mammals and other creatures which naturally feed on them. There are also all sorts of other natural dangers such as sudden changes in acidity, salinity, temperature and the oxygen or carbon dioxide content of the water supply.

It is necessary for the fish culturist to realize that all fish have a long racial history during which they have become adapted to certain physical and chemical conditions of their environment. This characteristic is directly reflected in their physiological make-up. When, therefore, fish are being reared artificially the culturist must realize that if he is to rear successfully his quota of fish he must not only eliminate any natural enemies but must see to it that the artificial environment is as good as the natural environment. This fact in itself explains the consequence to fish subjected to water depleted in oxygen below a certain point, due principally to overcrowding. Bacteria, fungi, parasitic protozoa and metazoa may thrive on or in such hosts that have become weakened. Usually, in nature, fish can choose their environment and thus live under nearly constant temperature and oxygen conditions. A rearing trough, tank, raceway or pool, which necessarily is relatively small for the number of fish reared therein, tends to become a constant habitat as to volume of water and, of course, as to amount of space available. On the other hand, under certain conditions, the temperature of the water and the amount of dissolved oxygen tend to fluctuate. In an artificial environment the fish can not get away from adverse conditions as they can in nature, and, consequently, may become subject to the gravest of dangers such as fluctuating oxygen and temperature conditions, muddy or turbid water, too

constant or intense light and other unfavorable conditions. As a result they are open to the attack of disease producing parasites such as bacteria, fungi and protozoa.

These are enemies introduced unknowingly by the culturist himself, and must be reckoned with if the 100 per cent success in rearing the fish from the egg to the adult is to be attained.

Overcrowding in fish hatcheries is the fundamental, besetting sin of all fish culturists. It is, in fact, a most costly error indulged in to no good or useful end whatever! Fry, one inch long, need twice as much space, the temperature and volume of water being constant, when they have increased to twice that size. If increased space and water volume are not provided, fungus, fin rot, gill disease, etc., may set in and kill off many, or all of the fish. This idea is not a mere fad of the biologist. In fact, it is founded on the mathematical law of the ratio of surface to mass. This law states that the surfaces of homologous solids are to each other as the squares and their masses are to the cubes of their homologous dimensions. A fish which has increased to twice its original diameter has therefore increased its surface four times and its mass eight times. It has reduced its proportionate surface by one-half, and its supply of food and oxygen in the same degree.

Selective breeding as to size, productivity, viability, disease resistance, and ability to thrive on inexpensive food and grow large as well as delicious in the shortest time possible are other fundamental purposes of artificial breeding of trout, salmon and other game fish.

As long as the realization of these purposes and aims are not actually attained, great losses at any time during the development of the fish may be experienced. In many cases, this actually happens. Fry, fingerlings and older fish are often crowded far beyond their ability to endure and if they do not die, they become stunted and deformed beyond their ability to recover. Moreover, very little attention is ever paid to selective breeding.

II. The Consequence of Over-Crowding

1. *Intestinal Fungisitosis (a new disease)*

In one of our hatcheries at which 400,000 brook trout fry *(Salvelinus fontinalis)* were being reared (1932), fungus pest developed and before it was studied scientifically, practically all the fish died. The fish were kept in seven cement tanks, 24 raceways and two pools.

By the week of July 9, 167,893 fingerlings had died from what was designated "natural causes." During this week, an additional number of 4,000 fingerlings died. Their size at this time was about two to three times larger than when first placed in the tanks. The average volume of living fish-flesh for the seven cement tanks was

approximately 61,704.8 cubic inches, or 35.5 cu. in. of fish to the gallon of water. For the 24 raceways, it was about 37,497.6 cu. in. or about 224 cu. in. of fish-flesh to the gallon of water. According to the report of the hatchery superintendent in charge, the fish became fungused in the upper tanks during the first week of July, and "two days later," those in the raceways below. During the week of July 16, more than 23,000 died. The fish were then bathed in sodium chloride solution. Still, during the week of July 23, more than 19,000 died. Then the fish were dipped in copper sulphate solution but with indifferent results, and the fish became gradually weaker and weaker. During the following week, 100,000 fingerlings died. At this time the fish exhibited no sign of fungus externally; likewise, no sign of gill disease. It was not a case of furunculosis. But the fish were weak, unable to buck the current and lay prostrate against the screens and along the bottom of the troughs.

Upon microscopic examination, it was found that the small intestine was completely occluded with fungus *(Saprolegnia ferax)*. The stomach was distended to the extent that the blood vessels could be easily seen externally in the body-wall on the ventral side. In fact, the intestine was completely honeycombed by the fungus, the free-ends of its filaments, in many cases, bearing club-shaped zoosporanges. The stomach was filled with gas. The large intestine contained feces which seemingly had remained there for some time. All the fish examined, whether dead, dying or semi-healthy individuals, were suffering from the occlusion of the small intestine by this disease, *i.e., intestinal fungisitosis*. About 50 per cent of the fish examined had their small intestine inhabited by *Octomitus salmonis,* a small flagellate protozoon. To what extent, if any, this flagellate was causing any disturbance in the physiological activities of the fingerlings is difficult to tell, since young trout often tolerate these as commensals in their alimentary canal. In the stomach was a large number of amoeboid cells, probably also commensals or symbiants.

Fungus may occur on the body and on the gills of fish inhabiting water low in oxygen, partly polluted, or in a confine too small in proportion to the number of fish present. That fungus would invade the intestine has not previously been known to science. However, fungi of a variety of species have been found in the alimentary tract of a number of hosts (man, bear, *et. al.*). *S. ferax* may, however, either before, or after having been washed off by external salt baths, invade the small intestine, ever the vulnerable part of young trout, and there ultimately cause death. Experienced hatchery superintendents were at loss to see "clean" fingerlings dying. Prior to our study of the situation federal and state hatchery superintendents were called in for consultation. They were unwilling to concede that overcrowding in such water, although already imperfect for trout rearing, was a contributing factor toward the loss

of the fish. Although the small intestine is one of the most vital spots in the body of any organism, they were unable to believe that fungus infection of this spot was the cause of the death of the fish. They looked for external trouble even in specimens they had preserved in 40 per cent formalin. Not finding any, they attributed the loss of the fish to an act of Providence. This plain statement of facts, with reference to the attitude of older fish culturists, is not meant as a criticism of such men, old in a valuable and important service, but rather as a sincere warning, an earnest request to use science and its methods when ordinary ways and methods of the layman fail.

Intestinal infection by fungus is a phenomenon probably of more common occurence than is realized at the present time. If such is the case, it may explain why fish sometimes die from "unknown" causes; when they succumb in what is thought to be good water after having been treated with customary salt baths, but not provided with water containing more oxygen than that in which they developed the fungus disease externally.

Fungus taking possession of the small intestine naturally would lead to a very weakened condition of the fish. But if this disease was the consequence of overcrowding, especially in water not of the best for the rearing of brook trout, the fish should recover if they were allowed water containing more oxygen than contained in the water in which the disease developed. This was found to be the case.

After the upper part of the rearing station had been cleared and cleaned from fish and wastes, the remaining sick fish recovered in this brook water with 64.23 per cent oxygen saturation, and a temperature around 15° C. (59° F.). Recovery commenced two days after the fish got a relatively large volume of unused water. The fish were placed in parallel raceways and allowed food only after they were able to buck the current of the water of the raceway. The recovery began after the fish had been thinned out to one-fifth the original number to the same volume of water in which they had contracted the disease and died very precipitously.

It is important to state that fungus externally on fish is really not a disease but rather a useful sign which when watched and heeded serves a useful purpose. Fungus, as such, does not occur in fish having a normal metabolic rate. A decrease in oxygen supply results in a slowing down of metabolism. Fungi are saprophytes which flourish in weakened hosts. A scarred tree or a wound on a fish are common examples. In such instances, metabolism is temporarily depressed, at least locally. Then spores of fungi germinate. The fluffy grayish growths on the neck or fins of trout had their beginning in spores. When such growth is observed on fish, it should be taken as a fair warning indicating the need of more or better water.

The following tables (I, II,) show, respectively, the physico-chemical and bacteriological nature of the water and the relation of fish volume to water volume at this station where the fungus described above developed.

TABLE I

Analysis of Water

Date	August 7, 1932
Temperature	15°C.
Turbidity	1 (very slight)
Sediment	2 (slight, gray, floc.)
Odor	2 (faint, earthy)
Color	8
Free Ammonia Nitrogen	.0240
Albumenoid Ammonia	.0820
Nitrate	.030
Nitrite	.000
Chlorine	1.20
Hardness	20.
pH	6.52
Dissolved Oxygen	6.52
Dissolved O_2% Sat.	64.23
Oxygen consumed	3.33
Biol. Oxygen demand	0.59
Total bacteria per c.c. at 37°C.	900
Total B. coli per c.c. at 37°C.	30
Confirmed on endo ager plates:	
10 c.c.	Positive
1 c.c.	Positive
0.1 c.c.	Negative
0.01 c.c.	Negative
0.001 c.c.	Negative

TABLE II

Relation of Water-Volume to Fish-Volume

Nature of the Confinement	Number of Fish per Unit	Size of Fish in Inches	Volume of Water per Fish in Gallons	Water Flowage per Second in Gallons	Oxygen Content of Unused Water	Temperature, °C. A	Temperature, °C. W	Consequences
Cement Tanks	17,143	2 to 3	.086	¼ to ½	64. 23% saturation or 6.52 p.p.m.	23	15	Total loss
Raceways	10,416	2 to 3	.016	.75				95% Loss
Upper Rearing Pool	10,000	2 to 3+	4.7	19.2				None
Lower Rearing Pool	30,000	2 to 3+	.7					None

Table I indicates some pollution which is shown by the ammonia present and by the amount of oxygen consumed in parts per million. The biological oxygen demand is low, however. This pollution was mainly due to the sewage and other wastes from the house of the hatchery superintendent and from a nearby barnyard. The pH of the water was 6.52 or nearly neutral. The water was soft, a condition common to most New Hampshire water. All the chem-

ical determinations in this table are expressed in parts per million. There were 30 *Bacillus coli* (pollution bacteria) and 870 other bacteria per cubic centimeter. *B. coli* are oxygen consuming organisms. They are frequently associated with other contaminating substances. Their normal habitat is the alimentary canal of man and other animals in whose body they live as commensals. Their presence, therefore, in natural water or foods is a clear-cut indication of fecal pollution to which growing trout never should be subjected.

Table II shows the relation of the fingerlings to the volume of water in their respective confines. It indicates pretty definitely that overcrowding of fish in the tanks and raceways was at least an imporant factor contributing to the cause of the death of the fish. The volume of water per fish 2 to 3 inches long was actually only two-thirds of a pint. It seems, had the fish not been so crowded, they would have lived in this partially organically polluted water. This opinion is substantiated by the fact that the less crowded fish in the rearing pools, whose water supply was the used deoxygenated water of the tanks and raceways, sustained no loss during the same time.

2. *White-spot Disease, Its Cause*

It has been claimed by fish culturists that white-spot disease in trout or salmon is due to rough handling of the eggs and subsequent bacterial infection. Indeed, in some instances, this may actually be the case. It occurs in both eggs and fry and is characterized by the appearance of an opaque, white area in some part of the embryo, for example, the yolk. A quotation on this topic from "Care and Diseases of Trout" by Dr. H. S. Davis is as follows:

"The opaque area is very noticeable in the semitransparent yolk, so that the disease is easily recognizable even in its early stages. White-spot may occur at any stage of development up to the complete absorption of the yolk sac but is more likely to appear during the early stages.

"There is still considerable uncertainty regarding the cause of the disease, and it seems probable that it is not always due to the same agency. The characteristic white-spot in the yolk is due to coagulation of the transparent yolk, causing it to become opaque. In many instances the coagulated yolk contains one or more kinds of bacteria, but this is by no means always the case. Frequently numbers of the so-called periblast cells, which are instrumental in the absorption of the yolk, are present in the white spots.

"The evidence points strongly toward the conclusion that white-spot is primarily caused by some injury to the eggs. Such an injury might produce coagulation of the yolk followed by increased activity of the periblast cells. If the egg membrane, or in the case of the fry, the layer of cells surrounding the yolk, is ruptured or perforated, any bacteria present may gain entrance and develop in

the yolk, which, of course, is simply nonliving organic material.

"The fact that several kinds of bacteria may occur in the white spots and that no one kind appears to predominate is strong evidence that the disease is not due to a specific infection. Furthermore, there is no indication that the disease is contagious, as is shown by the random distribution of diseased eggs among those that are perfectly normal.

"It is well known among trout culturists that white-spot is most likely to occur in eggs that have been shipped some distance or that have been handled roughly. This, of course, is in complete accord with the theory that the disease is usually the result of physical injuries. There is also evidence that in some cases the disease may have been the result of the eggs having been chilled or frozen."

Evidently the real cause of this disease has been missed by all fish culturists. It may be granted that rough handling of the eggs may be injurious and subsequently permit infection in that part of the embryo which is the least active. It is noted that Dr. Davis states that white-spot is most likely to appear in eggs that have been shipped some distance or that have been handled roughly. Furthermore, he writes that this "is in complete accord with the theory that the disease is usually the result of physical injuries." According to this author several kinds of bacteria have been noted in the white-spots and no one kind appears to predominate. This, he thinks, is strong evidence that the disease is not due to a specific infection. He bases this point of view on the known fact that the disease is not contagious which "is shown by the random distribution of diseased eggs among those that are perfectly normal."

No one will deny, of course, that rough handling of eggs may be injurious to the embryo which subsequently develops, and, therefore, care should be taken in the handling of eggs during stripping and the subsequent incubation period. On the other hand, as I shall point out later in more detail, the real cause for white-spot disease is lack of oxygen, or too many eggs or embryos per minute gallon flowage of water in the trough in which the eggs are to hatch. A point to demonstrate this case is in order.

At one of our hatcheries some of our brook trout *(Salvelinus fontinalis)* which spawn in September deposited about 60,000 eggs. These eggs were kept separately from other eggs taken later and special care was given to them, in as much as it was thought desirable to obtain as many adult fish as possible from these early spawned eggs. Some time after hatching, while the fry were still in the sac stage, the superintendent of the hatchery notified me that the fish were dying. The peculiar thing is that he had always lost, in the fry stage, the fish from the September spawned eggs. Previously, however, it had been thought that the loss of fry from September eggs was due to snow water mixing with the spring

water, but in the present instance, in order to protect the fry, the snow water had been eliminated from the spring water. Consequently the fry in question were being reared in water free from the destructive agents which had been thought to cause the loss of the early spawned sac-fry in previous years. Of course, it is an error to blame white-spot disease on snow water, for, most trout and salmon during their fry-stage are subject to exposure to ice and snow water in various degrees of concentration.

From microscopic examination of the white-spot, it was found that bacteria were present. The white-spots, being small areas in which the yolk had coagulated, appearing under the microscope very much like sawdust, whereas the yolk itself appeared as regular granular deutoplasm. A treatment was devised consisting of dilute acetic acid (1:2000), into which the fry were dipped for 15 seconds. It was thought that the highly penetrable qualities of this acid would affect the weak areas of the embryo first and might give the normal parts of the fry a chance to overcome the weakness of the white-spot. As a matter of fact, this method gave good results. The lot of fry having white-spot was divided into two groups. One group was left in the original trough and the other group placed in a different trough with an influent of five gallons flowage of water per minute. It was thought desirable not to treat all the fish with acetic acid at one time. The few that were treated, therefore, were placed in a third trough in order to observe the degree of recovery after twenty-four hours. This decision led us to stumble on an interesting fact: the cause of white-spot disease, described above.

The next morning it was found that both the fish in the original trough, containing the sick fish, and those that were placed in a second trough were cured without being dipped or treated with any chemicals. The dipped fish also recuperated. In other words, all that was necessary to cure white-spot disease was to thin out the fish by one-half or to increase the water to twice its original volume.

It should be stated that the eggs from whence these fry had developed were taken with special care, and to prevent temperature fluctuations during incubation, the ice and snow waters had been removed from the spring water. Careful measurements of the water, according to Leach, which had been done just prior to this time, led us to still more careful supervision of these fish providing them with at least the minimum necessary amount of water flowage per minute. However, Leach's formula, 1923, page 11, cannot be used with safety for eggs of fry in all waters.

According to this formula, "A hatching trough 14 to 16 feet long and holding from 25,000 to 45,000 fry will require 6 to 8 gallons of water per minute," or 4,200 to 5,600 fry per gallon minute flowage.

"On the basis of 100,000 fish it may be figured that the following amounts of water will be required:

"Fry up to feeding stage	30	gallons
Fingerlings 1 to 4 months old	50	"
" 4 to 6 " "	100	"
" 4 to 12 " "	200	"

"These amounts are ample and probably one-half as much would suffice if it were necessary to economize in the use of water."

That is, each of the following groups of fish of different ages and sizes would get along with one gallon of water per minute:

3,000 fry up to the feeding stage,
2,000 fingerlings from one to four months,
1,000 fingerlings four to six months old, and
500 fingerlings six to twelve months old.

TABLE III

Analyses of Water

Location	N. H. Reservoir	Head of Trough Series	End of Trough Series
Date	4-12-'33	4-21-'33	4-21-'33
Temperature of water, °C.	5	7.5	7
Turbidity	0	0	1 (vy. slt.)
Sediment	1	2 (slight)	2 (slight)
Odor	0	E-1 (vy. fnt.)	E-1
Color	5	5	5
Free Ammonia Nitrogen	.0060	.0100	.0160
Albumenoid Ammonia	.0100	.0100	.0100
Nitrate	.000	.000	.000
Nitrite	.000	.000	.000
Chlorine	1.20	1.20	1.20
Hardness	12.	15.	15.
pH	6.2	5.7	5.9
Dissolved Oxygen	8.78	8.56	8.94
Dissolved O_2% Sat.	68.5	70.6	72.5
Oxygen consumed	1.8	4.10	1.50
Biol. Oxygen demand	.88	1.01	4.32
Total Bacteria per c.c. at 37°C.	3	4	15
Total *B. coli* per c.c. at 37° C.	0	0	0
Confirmed on endo agar plates:			
10 c.c.	negative	negative	negative
1 c.c.	do.	do.	do.
0.1 c.c.	do.	do.	do.
0.01 c.c.	do.	do.	do.
0.001 c.c.	do.	do.	do.

In our experience, using pure spring water the analysis of which is shown in the above table, the amount of fish per minute gallon of flowage attempted to be reared according to the above quoted formulae of Leach is altogether too large. Fry fed on beef or sheep livers, or on sheep liver and heart or on a combination of sheep liver, heart, and salmon egg meal, or on assorted small fish and salmon egg meal grow at various rates. They grow faster when fed on liver and heart and salmon egg meal than when fed on raw meat or fish alone. Fish making a maximum growth will require more water than fish making an average growth. It has been demonstrated in our hatcheries that fish fed on beef liver require twice

the amount of water and twice the space indicated by Leach if they are to develop properly and not acquire diseases. When fed liver and salmon egg meal, which constitute a better food than liver alone, they require three times the amount of water stipulated by Leach. We have also discovered that when fry or fingerlings have the proper amount of water one gets a much more even growth amongst a given lot of fish in a given time than when the trough is crowded. It is also worthy of note that somewhat darkened diffused light also promotes a much more uniform growth in trout than when the fish are reared in troughs exposed to full light, *e.g.*, beneath a window either on the north or on the south side of the hatchery.

It is shown, therefore, that white-spot disease is due to overcrowding the eggs in the sac fry. In other words, it is due to insufficient water flowage or too little oxygen for the developing fish. Growth is impossible without oxygen. These facts can be readily substantiated when one observes troughs containing too many newly hatched fish.

The chemical nature of the water was satisfactory, as may be seen from Table III. The water is soft spring water collected for the hatchery from a spring-fed reservoir. The average pH concentration for this water, taken from the reservoir, from the entrance of this water into the hatchery, and from the end of a trough series containing approximately 20,000 1½-in. fingerling trout, on April 4, 1933 and at three similar situations, except the reservoir, on January 25, 1933 was 5.9, or a little high in acidity although not dangerous for trout as long as the temperature of the water was low. The water had a relatively high amount of dissolved oxygen in p. p. m. There was very little difference in the amount of dissolved oxygen in the water at the intake to the hatchery on either date.

SUMMARY

1. In the rearing of trout or salmon, as in other artificial propagation under control, one should aim at 100% success.

2. It should be possible to attain this if one would eliminate all factors injurious to the developing organism.

3. Oxygen is absolutely necessary for growth. Rapidly growing, developing organisms must have a normal amount of oxygen if development and growth are to be attained and if defects in body and the introduction of disease are not to occur.

4. Insufficient amount of oxygen for newly hatched trout or salmon, overcrowding of fry in the sac-stage, an insufficient amount of water flowage per minute are one and the same thing. They are the cause of "white-spot" disease.

5. White-spot disease can be cured by simply removing its cause. That is, if the fish have not been injured too much they will respond favorably to an increased supply of water.

6. Intestinal fungisitosis is also caused by an insufficient amount of oxygen, or overcrowding of the developing fish.

7. Like white-spot disease, intestinal fungisitosis and fungus pest as well can easily be avoided and can be cured by increasing the water flowage.

8. Care in the physical handling of young fish is absolutely necessary to attain healthy and rapidly developing fish. One should feed fry early; one should never allow fry to become weak from overcrowding; one should provide shade so that the fry and fingerlings during their development may have the opportunity to pass part of their time in the dark or in a shaded place during the day-time.

9. Fish growing in a uniformly darkened trough, in contrast to fish of the same age and size in troughs partly exposed, more or less, to diffused light of higher intensity, developed more uniformly.

10. Young fish frequently become constipated ("pot-bellied") when fed on too coarse food. In several instances, chinook salmon 2 to 2½ inches long actually exploded due to gas in the stomach caused by occlusion of the intestine.

REFERENCES

Agersborg, H. P. K.
1930. The influence of temperature on fish. Ecology, 11: 136-144.

Agersborg, H. P. K., and William J. Downer.
1931. The biology of a tropical stream in a frigid country. Annales des Sciences Naturelles, Zoologie, Ser. 10, 14: 281-302.

Davis, H. S.
1929. Care and diseases of trout. Bureau of Fisheries Document No. 1061: 119-171.

Leach, Glen C.
1923. Artificial propagation of brook trout and rainbow trout, with notes on three other species. Bureau of Fisheries Document No. 955: 1-74.

A QUANTITATIVE STUDY OF RAINBOW TROUT PRODUCTION IN ONE MILE OF STREAM

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Trout streams appear to offer a good opportunity for production studies. With concentration on a small area, it is believed that a reasonably accurate quantitative picture of the fundamental food supply can be worked out.

The one mile section of stream referred to in the title of this paper includes an actually measured length of 6,308 feet (1.19 miles) along Big Spring Creek near Leesburg, Va., from the outlet of the head spring to a self-cleaning screen constructed early in the summer of 1932. The operation of the screen during the fall and winter of 1932-33 was so spasmodic that its effect on the retention of fish in the section during the past year is considered negligible. Some problems in the operation of the screen have been solved this year; however, with the result that it has been kept running continuously with the exception of three days since May 30.

The plan of study of the trout production in the creek has been as follows: All pools were numbered and all pools and riffles were measured from the head spring to the screen; the point of capture of each fish could thus be recorded. Each fish was measured from the tip of the snout to the fork of the tail and subsequently weighed. This data was used in determining condition factors of the fish and production in pounds per acre of water surface. Scale samples were removed from each fish for age determinations. Finally, the stomach was removed and the items of food identified, counted, and in some cases weighed.

The section of creek in which this production study was made is one that has contained trout for years. It is located on the private property of a single individual who has not permitted fishing in the creek for many years. The stream has been stocked in the past, but no records are available of the plantings, the last of which seems to have occurred four or five years ago.

The creek flows through open pasture land for about one-half (3,320 feet) of its length in the experimental section. Except for a few sycamore trees, thorn, and haw bushes 52.6 per cent of its length is exposed. These few sycamores and bushes, however, are valuable assets. The remaining 47.4 per cent of the length of the section is shaded to a large extent by sycamore and elm trees, thorn and haw bushes. The banks of the creek rise two to six feet above the bed. They are steep particularly in the upper half of the sec-

tion where the stream has cut sharply at the turns producing under-cut banks. The source of the stream is a large spring pool with a maximum depth of about three feet. Production in the creek has been considered apart from this head pool in which 22 fine rainbow trout averaging about a half-pound each were counted at one time. The volume of water leaving the spring has been estimated at between 1,000 and 1,300 gallons per minute. From the head spring to the screen, the creek is a succession of pools and riffles. The aggregate total length of 84 pools is 4,010 feet; of 83 riffles 2,298 feet. The average width of the creek computed from 389 cross measurements is 11.4 feet. The area of surface water, therefore, is roughly 1.65 acres. The nature of the creek bed throughout the section is quite uniform. The riffles, except for about 595 feet, are composed of coarse quartz gravel with stones ranging from about one-fourth of an inch to four and a half inches in diameter. The average stone is about the size of a hen's egg. During severe freshets these stones are moved about resulting in a great destruction of mayfly nymphs (principally *Baetis*), fresh water shrimp *(Gammarus fasciatus)*, and young crayfish. In the excepted 595 feet of riffles and in 425 feet of pool bottoms are scattered large conglomerate rocks of coarse gravel embedded in a limestone matrix. The under-water surfaces of many of these rocks are often covered with moss which harbor large numbers of caddis larvae and pupae of *Hydropsyche* and *Glossosoma*, nymphs of mayflies, shrimp, larvae and pupae of the craneflies *(Antocha)*, a few parnid beetles and their larvae, and a few midge fly larvae. As much as 7.0 grams, wet weight, of fish food organisms have been removed from a square foot of rock surface. The production of natural food in the gravel riffles is much less, and it is doubtful if it would average as much as three grams per square foot. Water cress, usually thinly scattered along the margins of riffles, occurs about two-thirds of the distance down from the head spring. This cress was inhabited by large numbers of *Gammarus*. The bottoms of all pools with few exceptions are firm gravel, covered with a thin layer of silt, or firm clay and gravel embedded. The current and crayfish have combined to form many hiding places for trout by piercing many small round holes in the clay banks. The larger trout in the stream remain in these holes or beneath under-cut banks, and one walking cautiously along the banks would seldom catch a glimpse of a fish lying in the open.

The stream was stocked with 700 rainbow trout fingerlings on August 10, 1932. These averaged 76.45 m.m. in length and weighed 6.23 grams each. Later, on August 16, 300 somewhat larger fish averaging 10.8 grams each were added as part of an experiment. Some of these fish (not exceeding 50) were later removed for examination of their stomach contents.

Results

A. Fishing Effort

A total of 93 rainbow trout and one brook trout were captured with hook and line in 123 hours of fishing as tabulated in table 1, an average of 0.76 fish per hour. One rainbow trout, measured but not weighed, was found dead. Its weight was estimated at 0.5 pound.

TABLE 1

Fishing Effort. 1933.

Date	A	B	C	D	E	F	G	H	I	J	K	L	M
May 28	1-0.5	6-3	4-3			4-3	5-3	5-3					
June 2	3-7								4-7				
June 4	2-6	5-6		2-1.5	2-1.5	2-3	5-5						
June 11	2-2		0-2			1-1.5	2-1.5	1-1.5					
June 22	2-7.5	5-4.5								3-7.5	4-9		
June 30	1-2	6-2					1-2					1-2	2-2
July 23	3-3	0-3				1-3	0-3						
Aug. 1	4-1					2-4							
Aug. 20	1-1												
Aug. 31	1-1	0-2	0-2			0-0.5							

EXPLANATION: The letters A, B, C, etc., represent persons who did the fishing in the creek. 1-0.5 under A, May 28 signifies that one fish was captured by A in one-half hour of fishing; on June 2, three fish were captured by A in seven hours, etc.

After 123 hours of fishing, the use of spinners and flies yielded few fish. It is known that a few large fish remained, but these profited by their experience on a line.

B. Production Data

A total of 49.03 pounds of trout were removed from the section. All were caught in pools. Only 35 of the total of 84 pools produced trout. The failure of many to produce was undoubtedly due to lack of shelter. The average maximum depth of all pools in the creek was 22.4 inches. However, the 22 deepest pools ranging from 27 to 43 inches deep, produced 32.14 pounds of trout or 65.5 per cent of the total weight. Incidentally, the heaviest trout in the stream (1.38 pounds) was captured in the deepest pool. The two largest fish, both 15.5 inches, were caught in two of the deepest pools.

During the fishing period, pool No. 38 produced a total of eight fish aggregating 5.055 pounds. As many as four large fish (averaging 0.538 lbs.) were caught in this pool in one day. The next greatest producer was pool No. 66 with ten fish weighing 4.317 pounds. Pool No. 57 produced five fish totaling 3.56 pounds, and pool No. 64 eight fish weighing 3.07 pounds. It was noted that these pools were well sheltered as well as deep. Pool 66 produced three trout in one day on two occasions.

It has been calculated that the entire area of the stream is about 1.65 acres. A production of 29.7 pounds of trout per acre is therefore demonstrated.

C. Condition Factors

The condition factor is a measure of the plumpness of a fish in relation to its length. It is found by dividing the weight in pounds by the length in inches cubed and multiplying the result by 100,000.

The average condition factor of the 92 rainbow trout for which it was calculated was 44.42. The highest factor observed was 53.96 for a specimen 11.13 inches long; the lowest was 33.97 for a 15.5 inch trout. The following table summarizes the condition factor data:

TABLE 2
Condition factors of rainbow trout in the experimental section

Length in inches	Number of fish	Average condition factor
7-9	13	43.89
9-12	64	44.95
12-15.5	15	42.57

D. Results of Age Determinations

A study of the scales of the trout caught during the current season showed that 84.95 per cent belonged to the second year class. That is, these fish have passed their first winter in the creek. Only 54.84 per cent of the fish showed a definite annulus or one area of closely proximating ridges. The remaining 30.11 per cent showed no period of retarded growth. It has been assumed in the latter case that these fish must have passed at least one winter. The average length of the definitely second year class is 9.93 inches. Twelve of this group attained a length of eleven inches or more while ten were between 10-11 inches long. Of the group of 28 fish showing no definite zones of retarded growth, twelve were 9-10 inches long, five were 10-11 inches, six were 11-12 inches, and five were less than nine inches in length.

Eleven fish (11.8 per cent) were three year old fish, two (2.2 per cent) were four years old, and one (1.68 per cent) a five year fish according to their scales. In the older fish, however, it was difficult to find perfect scales and these were ragged. The eleven three year olds averaged 12.9 inches in length, and included two 15.5 inch fish. The four year fish measured 14 and 14.88 inches respectively. The five year fish measured 13.5 inches.

The proximity of the section studied to the head springs assures a rather uniform annual temperature. It may be that the temperature has little to do with the formation of growth zones. Records of some of the warmest days this past summer show variations in temperature from 53° F. at 6.00 A.M. to 70° F. at 3.00 P.M. Food supply is suspected of having more to do with formation of growth zones than temperature. Gray and Setna (1931, p.58) have observed that wide rings can be laid down during the winter months and found that fish on a limited diet developed abnormally narrow rings.

Bhatia (1932, p.8) observed that seasonal variations in temperature seemed to have no effect on the growth of rings. He found that rainbow trout fed uniformly did not exhibit any periodic zones on its scales whether the temperature was normal, high, or low. In an earlier study Bhatia (1931, p.266) concluded that the width of the rings was determined by food supply and not temperature.

From the standpoint of the angler, at least, a yield of 79 fish must be taken to represent the result from a planting of 950 three inch fingerlings in the presence of larger trout, a return of 8.3 per cent. The fact is emphasized that the presence of the self-cleaning screen at the lower end of the experimental section could have influenced these results but slightly, if at all.

E. Food Studies

The result of food studies are summarized in table 3. Although a large part of the food of the trout caught on May 28, consisted of shrimp and crayfish, the remaining catches showed that these trout were quite independent of the stream for their summer food, living almost entirely on terrestrial insects. In June, the large brown June beetles were the principal items. Later in the summer, grasshoppers and ground beetles became more important. The presence of algae in considerable quantities in 15 of 77 fish is noteworthy. Metzelaar (1929, p. 150) found that 19.3 per cent of the food of 87 rainbow trout 9-11 inches long consisted of vegetation. He states (p. 147) that "the outstanding feature of the rainbow diet certainly is the 15 per cent vegetation, formed largely by filamentous algae."

TABLE 3

Summary of food studies

A. Principle items of food:

Rank	Common Name	Scientific Group	Frequency in 77 Fish
1	Shrimps	Gammarus	53
2	June beetles	Scarabidae	43
3	Crayfish	Cambarus	27
4	Ground beetles	Carabidae	18
5	Mayfly nymphs	Ephemeridae	16
6	Microscopic plants	Algae	15
7	Grasshoppers	Locustidae	12
8	Click beetles	Elateridae	11
8	Weevils	Rhynchophora	11
8	Midge larvae	Chironomidae	11
9	Water boatmen	Corixidae	8
10	Ants	Formicidae	7
10	Caddis larvae	Trichoptera	7
11	Caddis pupae	Trichoptera	6
11	Water Scavenger beetles	Hydrophilidae	6
12	Diving beetles	Dytiscidae	5
12	Wasps	Hymenoptera	5
12	Crickets	Gryllidae	5
13	Terr. sow bugs	Oniscidae	4
13	Unknown beetles	Coleoptera	4
13	Unknown beetle larvae	Coleoptera	4
14	Midge pupae	Chironomidae	3
14	Snails	Mollusca	3
14	Spiders	Araneae	3
14	Flies	Diptera	3
14	Crawling water beetles	Haliplidae	3

No evidence of cannibalistic tendencies was found in this study. One fish, however, was caught with a minnow as bait.

The astonishing amount of work which some of the rainbow trout have done to secure a comparatively insignificant weight of food is illustrated by the following observations on wet and dry weights of organisms consumed in large numbers by several trout:

TABLE 4

Wet and Dry Weights of Organisms Consumed by Rainbow Trout

Length	Number and Kinds of Food Organisms	Wet Weight (Grams)	Dry Weight (Grams)
15.5 in.	759 Gammarus (mostly intact-heads counted)		
	6 June beetles and one crayfish (length 14 mm.) Total	22.50	2.70
13.5 in.	857 Gammarus		
	6 crayfish (43, 31, 27, 37, 35, 25 mm. long) and 5 mayfly nymphs, one fly larva, 1.18 mm. in length		
	Total	24.0	3.40
11.75 in.	3 crayfish (lengths: 46, 40, and 32 mm.)		
	6 Gammarus (not weighed)	6.5	1.2
9.63 in.	633 Gammarus		
	Abdomen of crayfish	11.5	1.7
9.25 in.	742 Gammarus		
	1 crayfish		
	3 chironomid larvae	12.9	1.1
13.5 in.	55 June beetles (length 16-19 mm.)	35.5	6.5
10.25 in.	27 June beetles (length 16-19 mm.)		
	1 Ground beetle (19 mm. long)		
	1 Click beetle (13 mm. long)	17.0	3.2

The wet weight was determined after the food removed from the stomach had been placed on blotting paper for a minute or two. The dry weight was determined after thorough drying at 60° centigrade in an oven for at least 24 hours.

LITERATURE CITED

Bhatia, D.

1931. A critical study of the scales of two specimens of starved and excessively fed trout (*Salmo irideus*). Journal du Conseil, Vol. 6, No. 2, pp. 266-272.

Bhatia, D.

1932. Factors involved in the production of annual zones on the scales of the rainbow trout *(Salmo irideus)*. Journal of Experimental Biology, Vol. 9, No. 1, pp. 6-11.

Gray, J. and Setna, S. B.

1931. The growth of fish. lv. the effect of food supply on the scales of *Salmo irideus*. Journal of Experimental Biology, Vol. 8, pp. 55-62.

Metzelaar, Jan

1929. The food of the trout in Michigan.

Transactions of the American Fisheries Society, Vol. 59, pp. 146-152.

A SUMMARY OF FISHERIES RESEARCH

E. L. Wickliff

Chief Bureau of Scientific Research, Ohio Division of Conservation

I. British Columbia—Dr. Wilbert A. Clemens and co-workers, Pacific Biological Station, Nanaimo:

1. Stream and lake survey for the development of fish cultural policies.
2. The spawning run and angling fishery of Kamloops trout at Paul's creek.
3. Introduction of brown trout into British Columbia.
4. Factors in Cultus lake affecting the development and survival of young Sockeye salmon.
5. Untility of plankton nets and plankton studies.
6. Marine investigations.

—William E. Ricker, Biological Board of Canada, Pacific Salmon Research Station, Cultus Lake.

"During the past year limnological work has been continued on Cultus Lake, under the direction of Mr. R. E. Foerster and myself. The problems being attacked include the following:

1. "Study of the physical and chemical characteristics of the water of the lake, throughout the year.
2. "Study of the abundance and distribution of plankton organisms throughout the year, particularly of entomostraca.
3. "Study of the food of the fingerling sockeye salmon *Oncorhynchus nerka* in the lake, with reference to number 2.
4. Study of the food of predatory fish in the lake, chiefly squawfish *Ptychocheilus oregonensis* and dolly varden charr *Salvelinus alpinus spectabilis*."

"In addition, two problems of more general interest have occupied my attention:

5. "Study of the theoretical and actual efficiency of the various devices for collecting plankton; nets, traps and pumps. This is a continuation of the work reported in last year's Transactions.
6. Examination and criticism of the various standards of oxygen saturation in use today."

II. California—Dr. H. S. Davis and Dr. P. R. Needham, U. S. Bureau of Fisheries, Palo Alto:

A trout stream survey stressing the importance of environment. The object is to formulate a policy of fish culture and conservation with a scientific background.

—Dr. L. O. Snyder, Bureau of Fish Culture, San Francisco: Salmon studies.

—W. L. Scofield, State Fisheries Laboratory, Terminal Island:

"Our research program is concerned chiefly with studies of fluctuations in the supply of the more important commercial species of marine fishes in this State. This includes both natural fluctuations in abundance and changes caused by man's fishing. This means detecting signs of a lessening in the supply, especially determining the presence of over-utilization and suggesting remedial measures for legislation. Remedies involve knowledge of life history so that we are carrying on life history work in addition to population studies.

"The most important project is a study of the California sardine, started some fourteen years ago. Most of the research staff contributes to this study, either as special studies or assisting in carrying on the routine work of sampling the catch each season at the various fishing ports. A study of the tuna fishery is also cooperative with special assignments to different staff members. A study of our mackerel fishery has engaged the efforts of two staff members."

Sardines. "Results from past work with new contributions have been summarized recently in reports not yet published. Conclusions as to migrations have been drawn by H. C. Godsil. Godsil has also cleared up much of our confusion as to local populations in sardines. Frances N. Clark has also summarized, in reports not yet published, her own work and that of others as to movements of sardines along our cost, age at sexual maturity and growth rate. Frances N. Clark has also reported on the manner of sardine spawning, based on studies of ova samples. E. C. Scofield has reported the areas and extent of spawning by means of quantitative tow hauls for eggs and larval stages. Frances N. Clark has reported on time spent by fishermen in scouting for sardine schools as a measure of changes in abundance. The sizes of fish caught by different types of nets and in different localities have been reported by J. B. Phillips and C. H. Clark, who in addition have made a study of the relative destructiveness of various sardine fishing gear."

Tuna. "Aside from early reports, no important studies have been concluded. Within the last two years, several tuna investigations have been started and are now under way by several of our staff members. H. C. Godsil is investigating the causes of spoilage in refrigerated fishing vessels. Work on growth rate, movements and races has only started. D. H. Fry, Jr., has reported on weight loss by cleaning and cooking tunas in the canneries. Effects of present legislation are being investigated by H. C. Godsil."

Mackerel. "A study of the mackerel fishery was started four years ago. D. H. Fry, Jr., has conducted life history studies, especially growth determination and spawning. He has suc-

cessfully hatched the eggs and reared the larvae in connection with oceanographic work on spawning. Richard S. Croker has sampled the commercial catch and written a report (Fish Bulletin 40, now in press) on the fishery in general."

Flatfishes. "The trawl fishery for flounders is being studied by G. H. Clark. This includes administrative questions in need of solution, life history studies and an analysis of the boat catches."

Rock Bass. "Studies of this species were conducted by S. S. Whitehead and Frances N. Clark and reported by the latter."

Yellowtail. "G. H. Clark did some work on the sizes of this species appearing in the commercial catch, and S. S. Whitehead made an analysis of the boat catches."

Barracuda. "Life history studies by L. A. Walford were published, and a boat catch analysis was made by S. S. Whitehead."

Pismo Clams. "Population studies, originated by F. W. Weymouth, of the clams at Pismo Beach have been continued."

Oysters. "In cooperation with the U. S. Bureau of Fisheries, California is investigating and supervising oyster culture. Work for the State is being done by Paul Bennet. This work is not under the direction of this Laboratory."

Shrimps. "Life history studies of the shrimps in the San Francisco Bay region are being made by Hugh R. Israil. This work is not under the direction of this Laboratory."

III. Illinois—Dr. David Thompson, Illinois Natural History Survey, Urbana:

1. Determination of fish migrations from returns of tagged fish.
2. Age and rate of growth of important fishes.
3. General quantitative determinations of plankton and bottom organisms.
4. A comparison of population densities by means of standardized fishing methods.
5. Determination of fish population of a lake by clipping the fins of important fishes.

IV. Massachusetts—Dr. C. J. Fish, International Passamaquoddy Fisheries Commission, Woods Hole:

The effect of a proposed tidal power dam on the fisheries of the Quoddy region in the Bay of Fundy.

—J. Arthur Kitson, Supt. of Distribution, Division of Fisheries and Game, Boston:

Biological stream survey.

V. Michigan—Dr. Carl L. Hubbs, Curator of Fishes, Museum of Zoology, Ann Arbor:

1. Stream and lake improvement surveys.
2. Fish predators and forage fish.

—Dr. Paul S. Welch, Douglass Laboratory, Douglass Lake:
1. Life histories, plankton and bottom organism determinations.
2. Physical, chemical and biological surveys of lakes.

VI. New Brunswick—A. H. Leim, Acting Director, Atlantic Biological Station, St. Andrews:

"The following investigations in marine and freshwater biology have been carried on in 1932 and 1933. Studies in the life histories, food and distribution of the important food fishes, including the haddock, cod, herring, and hake in the bay of Fundy and near Halifax; life history of the lobster; growth studies of the scallop, clam and squid; reproduction and growth of oysters; sex reversal of oysters; effect of varying temperatures, salinities and of light on oysters, clams, lobsters and other aquatic animals; effect of oxygen content of the water on the development of oyster larvae; plankton of the Halifax area; hydrography of the bay of Fundy, Halifax, Shediac and Malpeque areas, and its relation to marine animals; primitive bacteria of sea water; yellow coloration in clams; life history of the salmon of the St. John river system and rivers emptying into Chaleur bay; observations on salmon in Apple River, N. S., food of salmonids; fall runs of salmon in the St. John, Magaguadavic and Digdeguash rivers; salinity relations of salmon; survey of Chamcook lakes and Loch Lomond, N. B., and Lake George, N. S.; disease in eel-grass; hydrography of the waters of the Halifax area; chemical investigations of sea water in the Halifax area (phosphates, oxygen, etc.); hydrography of Malpeque bay area, winter conditions; light in relation to water; effects of light on aquatic organisms; comparative surface water temperatures."

—R. O. McKenzie, Atlantic Biological Station, St. Andrews:

"For the past year or so I have been investigating the cod fishery of the outer, or Atlantic coast of the province of Nova Scotia, Canada. Besides investigating the cod fishery as a whole and its peculiarities in certain regions I have been working on the effect of the environment on the habits and movements and migrations of the cod in an attempt to determine some of the underlying principles responsible for the character of the cod fishery at various points along the shore.

"Up to the present our activities have been confined to the "inshore" regions as opposed to the "offshore" or "bank districts." Both regions are to be investigated eventually and it is hoped to be able to throw some more definite light on the relationship, if any, between the "inshore" and "bank" fisheries than exists at present.

"Dr. V. D. Vladykov of this station . . . . is working along somewhat similar lines on the haddock."

VII. New Hampshire—Dr. H. P. K. Agersborg, Dept. of Fisheries and Game, Concord:

Physical, chemical and biological studies of brooks, lakes and ponds in order to determine when and where to plant fish.

VIII. New York—Dr. Emmeline Moore, Research Biologist, Conservation Dept., Albany:

"A continuation of the stream survey started in 1926. The object is to formulate a scientific stocking policy for the streams, ponds and lakes.

"The plan devised at the outset brings the nineteen watersheds, lying whole or in part, within the boundaries of the State, into a twelve-unit project to be completed in a twelve-year period. Thus far the stint of the survey, 'a watershed a year,' has been realized and the completion of the entire project may be hopefully consummated within the next four years.

"The project of the current year is the study of the Raquette River Watershed and the formulation of the stocking policy. A staff of thirty-eight scientists, including several well known fish experts has been recruited as heretofore, many from the educational institutions of the State; although several of the specialists have been drawn from other states. Field work is conducted from June 1 to September 15. The results of each watershed are incorporated in a report for the area, carrying besides the stocking policy several papers of importance which underlie the recommendations of policy. Colored plates, photographs, maps and graphs are additional features of the report."

IX. Ohio—Dr. R. C. Osburn, Stone Research Laboratory, Gibralter Island:

A cooperative program with the Ohio Division of Conservation of physical, chemical and biological studies of the western end of Lake Erie.

—Dr. J. P. Visscher, Western Reserve University, Cleveland: Distribution of entomostraca of northern Ohio.

—Cooperative programs between the Division of Conservation and several of our high schools, colleges and universities.

X. Ontario—Dr. W. J. K. Harkness and co-workers, Dept. of Biology, University of Toronto:

1. Variations in ciscoes.
2. Determinations of bottom organisms.
3. Seasonal changes in the physical and chemical condition of water, with special reference to oxygen supply.
4. Age, rate of growth and food studies of Nipissing fish.

XI. PENNSYLVANIA—C. R. Buller, Assistant Commissioner, Harrisburg:

1. Stream survey to determine a suitable fish stocking policy and a classification of the waters for stocking warm and cold water species.
2. Effects of pollution on aquatic life.

XII. QUEBEC—G. R. Lane, Lucerne, Quebec:
Chemistry of one hundred lakes.

XIII. U. S. BUREAU OF FISHERIES—Elmer Higgins, Washington, D. C.:

1. Shellfish and commercial fisheries investigations.
2. Tagging experiments.
3. Compilation of statistics.
4. Freshwater fishery investigations.
5. Cooperative projects.
6. The use of fish screens and ladders in conserving the run of anadromous fish.
7. The effects of pollution on fish and mussels.

XIV. WASHINGTON—Dr. W. F. Thompson, International Fisheries Commission, Seattle:

1. "Studies of the rate of growth of the halibut, its age at maturity, and age composition of the commercial catch, by H. A. Dunlop."
2. "Migrations of the halibut by means of tagging experiments, by J. L. Kask."
3. "Early life history of the larvae and quantitative determination of the abundance of spawn by means of plankton nets, by R. Van Cleve and L. D. Townsend."
4. "Biological statistics of the halibut fishery showing variations in abundance of halibut and their causes, by F. H. Bell."

"I have been personally concerned in the biological statistics and the larval life history as well as the administrative work of the International Fisheries Commission in regulating the halibut banks.

"Other work under my supervision has been the age determinations of the albacore, by R. T. Smith and C. H. Ellis; the systematic study of the lantern fishes taken by the International Fisheries Commission, by W. M. Chapman; the spawning habits of the silver smelt *Hypomesus,* by myself and staff; the life history of the silver smelt, by J. Hart; and the fluctuations in abundance of albacore and their correlation with temperature, by F. M. Wood."

XV. Wisconsin—Dr. Chauncey Juday, University of Wisconsin, Madison:

"*Physics*—In addition to the color, transparency and temperature of the water in our lakes, we have been engaged in a study of the penetration of solar radiation into the water. Such a study is fundamental to an understanding of the process of photosyntheses. We have determined not only the quantity but also the quality of the solar energy found at different depths in different types of lakes, such as those with very clear water and those with brown stained water. In the highly colored waters the solar energy is cut off very rapidly, while in the clear water lakes as much as one to four per cent of the solar energy delivered to the surface of the lake may reach a depth of fifteen to eighteen meters. In the highly colored waters the solar energy may be reduced to one per cent at a depth of two meters.

"*Chemistry*—We have made a general chemical survey of some 540 lakes in this lake district. Some of the lakes have very soft waters, with very low specific conductance, while others are moderately hard and have medium quantities of electrolytes. Likewise the pH of the very soft water is on the acid side of the range, while the harder waters in some cases are quite alkaline (pH 8.5-9.0). Reports are now in preparation on other phases of this chemical survey.

"A study of the organic content of the water of the different types of lakes has also been made. Determinations of organic carbon, organic nitrogen and ether extract have been made, so that the amount of protein, carbohydrate and fat can be computed. The clear soft water lakes contain the smallest amount of organic matter and the highly colored lakes the largest amounts. The quantity of plankton has also been determined so that the amount of organic matter contained in it is known. Large samples of plankton have been obtained from a considerable number of the lakes and these have been analyzed for organic carbon, organic nitrogen and ether extract, so that the general food value of this material is now known.

"*Botany*—During the past two summers experiments have been made to determine the photosynthetic activities of the algae at different depths in several lakes—including those having clear transparent waters as well as those with highly colored waters. This work has been used so that the actual amount of solar energy delivered to the surface of the lake during the period of the exposure of the algae at different depths is known, and observations with the pyrlimnometer show the quantity and quality of the light at the different depths.

"A quantitative and qualitative survey of the large aquatic plants in a number of lakes has been correlated with reaction of

the substratum in which they were found growing and with the character of the water.

"*Zoology*—Quantitative studies of the centrifuge plankton have been made. The weight and chemical composition of some of the plankton crustacea, which serve as fish food, have been studied.

"During the present summer we are carrying on an experiment to determine the total fish population of a lake. We now have sufficient data to make such a determination on one lake and hope to secure enough for another before the end of the season."

In reviewing the above papers one is impressed with the fact that a number of states and provinces are now engaged in determining the suitability of their waters for the several species of fish stocked from hatcheries, and also for the wild fish. The environment is now considered a major factor for successful fish planting and in the future habitat control or improvement seems to be a necessity or the many thousands of fish planted will not give the sportsmen full value for their fishing license money. This may be brought about by a better understanding of the problems involved through the medium of a scientific approach.

SOME PHYSICAL, CHEMICAL, AND BIOLOGICAL STUDIES OF IMPOUNDED WATERS IN OHIO

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Physical, chemical, and biological investigations of thirteen lakes in Ohio, twelve of which were artificial, were made during the autumn of 1932, by the Bureau of Scientific Research of the Ohio Division of Conservation. At various dates throughout the past summer (1933) four of these lakes were resampled and two creeks and one river, the waters of which were impounded by low dams, were also added to our list.

These investigations were begun with three objects in view. *First,* for the purpose of securing comparative data on the value and productivity of impounded waters. *Second,* to compare impounded waters of various ages, and *third,* to attempt to determine the relative value of natural and artificial bodies of water. Since the three "low dam" projects have been added to our list a *fourth* question has arisen; what effect does this type of dam have on the chemistry and biology of the stream, and is it helpful or harmful?

Samples were taken and counts made per unit measure of both microscopic plants and small crustaceans as well as for animal organisms which live on the bottom. The microscopic plants are utilized as food by both the small crustaceans and the bottom organisms. Newly hatched fish exist almost entirely on small crustaceans and some continue to feed on them throughout their life. Generally, however, as the fish grow larger they feed largely on the bottom organisms. Thus it can be seen that the greater number of these forms found indicates a greater available food supply for the young fish.

Chemical analyses were made for dissolved oxygen (which the fish and animal fish food need for breathing), and free carbon dioxide (which is given off by these animals during respiration and by decaying plants and animals). The acidity of the water was measured in terms of pH with the LaMotte colorimeter. A pH of 7 indicates neutral water. Anything over seven indicates alkaline water and anything under seven indicates acid water. The temperature of the water was taken with the Negretti-Zambra reversing thermometer. Turbidity was measured with the standard Secchi disc.

The organism counts do not necessarily indicate either a maximum or a minimum for any particular lake or stream in as much as their normal fluctuation is often very large. Similarly the chemical data may indicate any extreme condition due to the season in which the analyses were made. The value of this data rests almost entirely in showing whether or not a particular body

of water, or a particular sample from that body of water, is capable of supporting an adequate population of fish food and in showing other conditions of that water.

Sampling stations were so arranged in the larger lakes that samples representative of the lake were taken. In the case of the "low dam" waters one or more samples were taken in the impounded portion and one or more in the normal stream. The average data from each lake or stream will be given in the following discussion, and on the accompanying graphs.

Turkey Foot Lake was the only natural lake studied. It was located in the southern portion of Summit County, and covers an area of about 307 acres. *Buckeye Lake,* the old Licking Reservoir, was situated in parts of three counties: Licking, Fairfield, and Perry. It was the oldest artificial lake examined and covered an area of about 4,200 acres. The remainder of the reservoirs in order as to their age were: *Lake St. Marys* in Mercer and Auglaize Counties, about 15,500 acres; *Loramie Reservoir,* in Shelby County, occupied about 1950 acres; *Indian Lake,* in Logan County, covered about 7200 acres; *Griggs Reservoir,* in Franklin County, covered about 364 acres; *Lake Alma,* in Vinton County, covered about 80 acres; *Lake Rockwell,* in Portage County, covered about 2700 acres; *O'Shaughnessy Reservoir,* in Delaware County, covered about 832 acres; *Mt. Gilead Reservoirs,* in Morrow County, (composed of two very small lakes whose total does not exceed 18 acres); *Guilford Reservoir,* in Columbiana County, covered about 380 acres; and *Meander Lake,* in Mahoning and Trumbull Counties, covered about 2012 acres.

Buckeye Lake was the oldest Reservoir, being about 96 years old when sampled in 1932. Meander was the youngest being sampled first when but 7 months old.

The two creeks containing small dams were: *Beaver Creek,* a tributary of the Little Miami River, which is impounded by 3 dams each about 300 yards from the other, located in Greene County; and *Wolf Creek,* a tributary of the Miami River, which is impounded by 10 dams each about 100 yards from the other, located in Montgomery County. The Maumee River at Independence below Defiance, in Defiance County, was also impounded by a low dam. Several samples were taken from each of these impounded portions, as well as from the normal stream in order to get comparative data.

The chemical data of the lakes varied greatly in most cases with, apparently, little correlation with the plant and animal distribution. (See accompanying graphs). Dissolved oxygen was found to be the highest at Mt. Gilead with an average of about 9 parts per million (milligrams per liter—about .0029 ounces per quart), and lowest at O'Shaughnessy with an average of 3.5 parts per million. The acidity varied from 8.5 in Indian Lake to 6.3 in Lake Alma. The general average was over 7 in every Lake except Alma.

Quantitatively the small crustacea were most numerous in Guil-

ford Reservoir, decreasing to a minimum in Indian Lake. The microscopic plants were most numerous in Rockwell Reservoir and decreased to a minimum in Lake Alma. (These are given on the accompanying graphs as "number per liter"—a liter is almost a quart).

During the summer and autumn of 1933 four of these lakes were resampled. They were Meander, Guilford, Alma, and Buckeye. Variations due to seasons and other normal changes were noted of course but they did not transgress abnormally from the 1932 data.

This data indicates that the microscopic plants and small crustacea may be abundant in each of the reservoirs and apparently is not influenced to an abnormal degree by chemical or physical conditions in the lakes except in some of the deeper samples. In some of the newer deep reservoirs a depth contour line may be drawn where oxygen decreases very suddenly. This, of course, influences the distribution of life very greatly, few forms being found where oxygen is low. In Meander Lake this was close to 5 meters (17 feet) in 1933. Thus in Meander Lake the water below that depth is worth very little for either fish life or fish food. It is believed that this condition is probably caused by the new bottom which is rapidly undergoing decomposition.

March 14, 1933, Mr. Wm. Van Arnum, chemist at Meander Lake, took an oxygen sample from the bottom of the lake, in the deep end (14 meters—about 47 feet) which analyzed to 12.9 parts per million. During our investigations of 1933 no oxygen was found below 8 meters, (27 feet). Winter conditions evidently give the lake a breathing spell.

Twelve types of bottom organisms were found including insects, worms, and mussels. Bottom organisms were most numerous in Lake Alma and least numerous in Lake St. Marys. Here again correlation with the chemical data is difficult to make. Often the bottom organisms would be most numerous where dissolved oxygen was low and vice versa.

Dissolved oxygen decreased to a nearly lethal amount in the impounded portions of Wolf Creek (from 7 p. p. m. in the normal to 3.5 p. p. m. in the impounded portion), and considerably in Beaver Creek although not alarmingly (from over 7 to 6 p. p. m.). It is believed the low oxygen content in Wolf Creek was due to the numerous dams so close together, and the impoundation of the normal riffles. Obviously aeration by the dams themselves is not enough to offset the loss of the riffles.

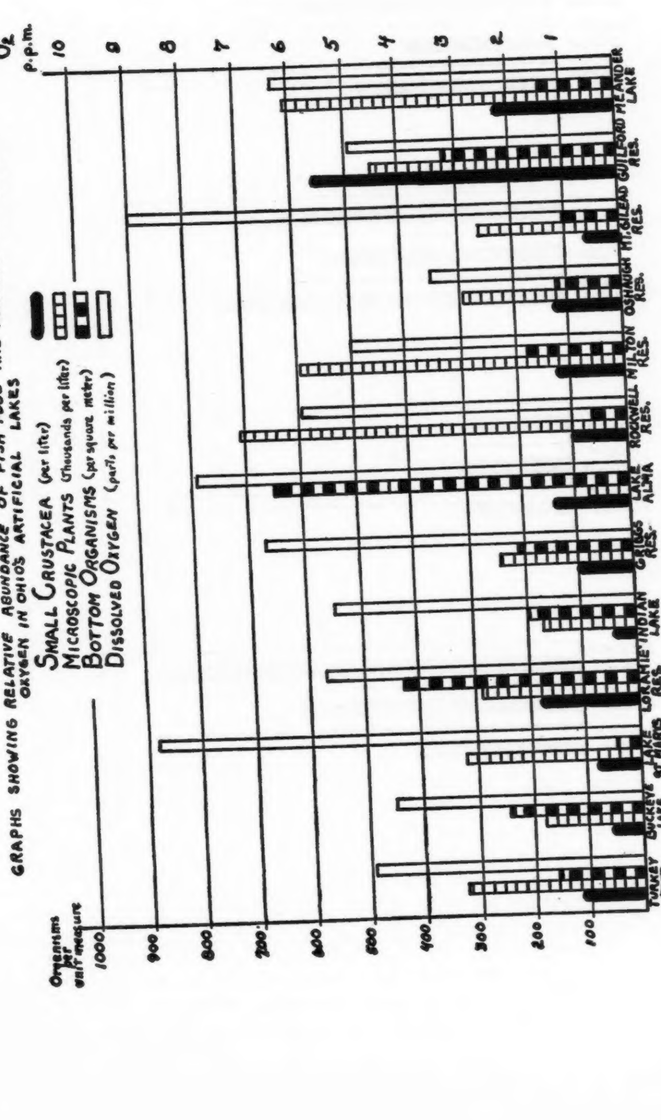
Bottom organisms increased tremendously in the impounded portions of Beaver Creek over the normal portion whereas in Wolf Creek the normal portion is fairly high in bottom life and is exceeded but little in the impounded portion. The productivity of bottom organisms in the impounded portion would undoubtedly

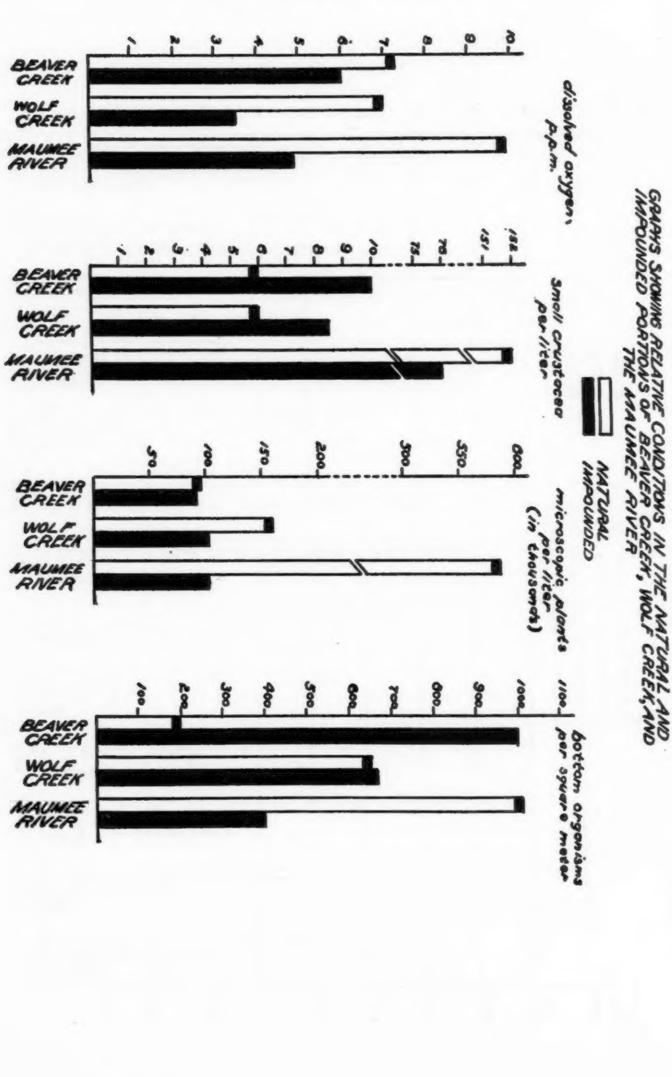
be raised considerably if more natural riffles were provided. The lack of the natural riffles it is believed also caused the "silting in" process noticed behind the dams in Wolf Creek.

The increase in small crustacea in the impounded portions of both creeks is encouraging. The decrease in microscopic plants in the impounded portions is of little importance in that they vary considerably within a few days and the lack of them does not indicate that they can not be abundant.

The chemical and biological conditions became much worse in the impounded portion of the Maumee River at Independence. Impounding the water destroyed the natural riffles where insect larvae (potential fish food) abound, caused the dissolved oxygen to decrease sharply, and evidently caused a slight increase in carbon dioxide and acidity. The pool formed by the dam was not a natural pool and the bottom is apparently flat stone normally covered with sand but which is kept scoured clean by currents. This is, of course, not productive of insect larvae or other fish food.

In conclusion the results of our investigation indicate, *first,* that the impounded waters studied are capable of supporting a normal small crustacea and microscopic plant population, although the chemical conditions may influence, to some extent, larger organisms; *second,* that waters over a year in age may have abundant small fish food although bottom forms may be influenced to a considerable extent by the condition of the bottom which in the younger lakes, especially the deeper portions, is not yet capable of supporting life, and which in turn influences the chemical nature of the water; *third,* that artificial lakes are as capable of producing small fish food and bottom organisms as are natural lakes providing other conditions, as nature of the bottom, protection from wave action, etc., are equal, and *fourth,* that low dams may be helpful in the production of microscopic life, bottom organisms, and lurking pools providing they are placed far enough apart for proper aeriation of the water by means of normal riffles between.


GRAPHS SHOWING RELATIVE ABUNDANCE OF FISH FOOD AND AMOUNTS OF DISSOLVED OXYGEN IN OHIO'S ARTIFICIAL LAKES
SMALL CRUSTACEA (per liter)
MICROSCOPIC PLANTS (Thousands per liter)
BOTTOM ORGANISMS (per square meter)
DISSOLVED OXYGEN (parts per million)
Organisms per unit measure
1000
900
800
700
600
500
400
300
200
100
O_2 p.p.m.
10
9
8
7
6
5
4
3
2
1
TURKEY FOOT
BUCKEYE LAKE
LAKE ST. MARYS
LORAMIE RES.
INDIAN LAKE
GRIGGS RES.
LAKE ALMA
ROCKWELL RES.
MILTON RES.
OSHAUGH RES.
MT. GILEAD RES.
GUILFORD RES.
MEANDER LAKE


GRAPHS SHOWING RELATIVE CONDITIONS IN THE NATURAL AND IMPOUNDED PORTIONS OF BEAVER CREEK, WOLF CREEK, AND THE MAUMEE RIVER
NATURAL
IMPOUNDED
dissolved oxygen, p.p.m.
small crustacea per liter
microscopic plants per liter (in thousands)
bottom organisms per square meter
BEAVER CREEK
WOLF CREEK
MAUMEE RIVER

SUMMARY OF LIMNOLOGICAL INVESTIGATIONS IN WESTERN LAKE ERIE IN 1929 AND 1930*

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AND

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For many decades Lake Erie supported a highly productive commercial fishery, but within the past twenty-five years there has been an alarming decline in production of the more highly prized species, in spite of an increase of fishing intensity. Following the virtual collapse of the cisco fishery in 1925, fishermen, conservation officers, and fisheries biologists alike realized the necessity of a scientific investigation to determine the cause or causes of the decline, and to determine possible remedial measures.

A number of explanations were offered for the decrease of the catch. Fishermen were persistent in their claim that pollution had made parts of the lake unsuitable for fishes. Attention was directed particularly to the western part of the lake because of a number of conditions which make it especially subject to pollution, and because of its importance in the fishery. The conditions which make it especially subject to pollution are: (1) the presence of large industrial communities on the shores of Maumee, Raisin, and Detroit Rivers, which empty into this part of the lake; (2) the extreme shallowness and consequent small volume of water; (3) the presence of two peninsulas and numerous islands which partially separate this area from the rest of the lake, and which tend to prevent free outflow of water. The importance of Western Lake Erie in the fishery arises from the facts that: (1) large numbers of fish are caught there; (2) the area is used as a spawning ground by all of the commercial species except, possibly, the blue pike-perch.

The Division of Conservation of the State of Ohio was the first to investigate the degree and extent of pollution with reference to its effect on the fishery of Lake Erie. In the month of August, 1926, and in autumn and winter of 1927, special parts of the lake, particularly along the Ohio shore from Toledo to Cleveland, were studied. In 1928, 1929, and 1930, work was concentrated on the part of the lake west of Point Pelee. In the interests of brevity and convenience of presentation, the summary presented here is based on the results obtained in 1929 and 1930 only. Moreover, the results of physical and bacteriological studies are not included here. A more comprehensive report, covering the results

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of the five years of study, has been completed and will be published later.

The Franz Theodore Stone Laboratory of Ohio State University, through its director, Dr. R. C. Osburn, has been in close cooperation with the Division of Conservation throughout the investigation. In 1929 and 1930 a third cooperating organization, the United States Bureau of Fisheries, was added. After 1927 the work was under the direct supervision of Mr. E. L. Wickliff, Chief of the Bureau of Scientific Research, Division of Conservation. The writers wish to acknowledge the contributions made by the many investigators, and others, who have been connected with the survey.**

The general plan of investigation was as follows: It was assumed that the offshore areas of the lake, far from sources of pollution, would be most nearly normal, and that the areas near the rivers would show the maximum effect of pollution. Accordingly the lake was divided arbitrarily into five sections, and parallel studies were made in each section to facilitate comparisons of the results. The offshore area, near the islands, was designated the Island Section, and areas near the mouths of the four rivers studied were designated the Portage River, Maumee Bay, River Raisin, and Detroit River Sections (Figure 1). With minor exceptions the field work was done in the months of April to October, inclusive.

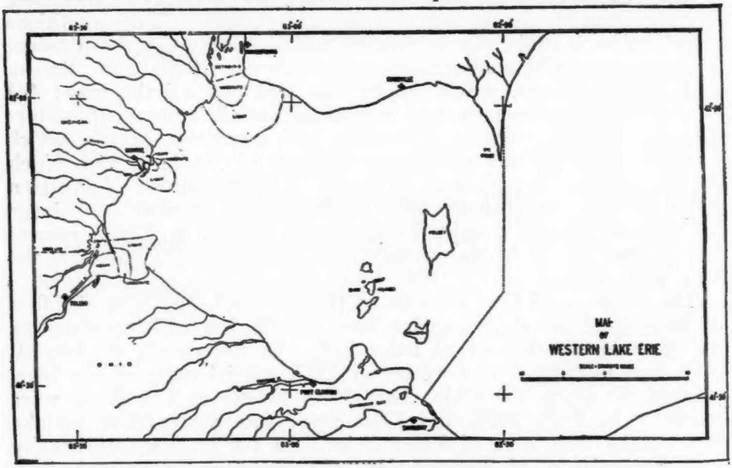

Figure 1. Western Lake Erie. Boundaries of sections, and locations of principal stations (indicated by numbered circles). Data were obtained at more than 100 stations not shown on the map.

**The survey staff consisted of the following investigators: Elbert H. Ahlstrom, William Beaver, C. Dwight Marsh, Barbara Metz, Casimer J. Munter, Lee Roach, E. B. Ruth, L. H. Tiffany, W. M. Tidd, Doris Ann Wright, Merle K. Young, all of the Ohio Division of Conservation; and Stillman Wright of the United States Bureau of Fisheries.

Chemistry

In the Island Section the oxygen content of the surface water ranged from 7.1 to 13.0 parts per million, and from 83 to 133 per cent of saturation. Almost all of the samples fell between 90 and 99 per cent of saturation. Free carbon dioxide ranged from —2.5 to +3.1 parts per million; methyl orange alkalinity (in terms of calcium carbonate) from 85 to 103 parts per million; pH from 7.7 to 8.4. In general the chemistry of the surface and bottom water was nearly the same. Only one case of nearly total depletion of oxygen in the lower water was found in the two seasons of study. The low oxygen content (8.6 per cent of saturation) was found in the eastern part of the Island Section near the close of a period of temporary thermal stratification, and apparently was restricted to the lower three meters of water.

The average amounts of the different forms of nitrogen in the Island Section were as follows: free ammonia, 0.013; albuminoid ammonia, 0.151; nitrite, 0.005; nitrate, 0.10 (Part per million). While it is probable that the nitrogen content has been increased by pollution, it is equally probable that the additional demand upon the dissolved oxygen has been small as compared with demands resulting from natural phenomena. From a chemical point of view, polluting materials known to enter the lake apparently have had no harmful effect on the water of the Island Section.

The chloride content of Lake Erie is higher than that of other of the Great Lakes. Chloride has little value as an index of pollution in Lake Erie because of the numerous natural sources of sodium chloride in the drainage basin.

A number of chemical samples were taken in Western Lake Erie near the mouths of four tributary streams (Portage, Maumee, Raisin and Detroit Rivers), and a few were taken in the rivers themselves. All of the rivers are known to receive sewage from municipalities located on their shores. In relation to its mean discharge, Maumee River receives sewage from the largest population; in this respect River Raisin is second; Portage River is very probably third; and Detroit River fourth. Over considerable areas in and near the rivers the bottom was covered by organic debris, which would have a marked effect on the chemistry of the water immediately in contact with it. The following summary applies only to the water one meter or more above the bottom.

Parts of the lake in which there was definite evidence of pollution, as indicated by high albuminoid ammonia, were characterized by low nitrite and nitrate as compared with parts of the lake in which the evidence of pollution was less definite or lacking. This is believed to have resulted from the utilization of nitrite and nitrate by plankton algae, for there was a direct relationship between the abundance of phytoplankton and the intensity of pollution.

Chemical results obtained in Portage River at Port Clinton, and in the lake near the mouth of the river indicate light pollution. The only definite evidence of pollution was in the content of albuminoid ammonia, which was somewhat higher than in the Island Section. In most of the samples the dissolved oxygen content was in excess of 90 per cent of saturation, and in no sample was it less than 77 per cent of saturation. Correspondingly satisfactory results were obtained for free carbon dioxide and pH. It may be concluded that pollution in Portage River has had no harmful chemical effect on the water of Western Lake Erie.

Maumee River near its mouth was heavily polluted as indicated by high free and albuminoid ammonia (0.618 and 0.708 part per million), and by low dissolved oxygen (not exceeding 49 per cent of saturation). Immediately outside the mouth of the river free and albuminoid ammonia were consistently high, and there was definite evidence of the effect of the river water at a distance of 8.5 miles from the mouth. The oxygen content immediately outside the mouth was sometimes low and sometimes high (range: 12 to 112 per cent of saturation), but there were no marked withdrawals of oxygen at a distance of 2.25 miles or more from the mouth of the river. In Maumee Bay the harmful chemical effect of the river water appeared to be restricted to a small area near the mouth of the river.

River Raisin at its mouth was definitely polluted as shown by the high albuminoid ammonia (mean, 0.433 part per million), and by low oxygen content. In one case there was total exhaustion of oxygen. The effect of pollution was evident in the analyses for albuminoid ammonia in the lake at a distance of at least two miles from the mouth of the river, but no marked withdrawls of oxygen definitely referable to pollution were noted at a distance greater than one-half mile, and only then in water recently discharged from the river. Thus, the harmful effect of pollution apparently was restricted to a very small area near the mouth of the river.

There was no definite chemical evidence of pollution in the lake near the mouth of Detroit River, nor in the river near its mouth. In most respects the chemical results were similar to those obtained in the Island Section. On the average there was less decomposing organic matter, as shown by albuminoid ammonia, than in the Island Section. In most of the samples the oxygen content was in excess of 90 per cent of saturation, and in only a few samples was it less than 80 per cent of saturation. Doubtless the nitrogen content of the river water has been increased as a result of pollution, but probably the increase has been too small to have an appreciable effect on the oxygen content of the water. It may be concluded that pollution in Detroit River has had no harmful chemical effect on the water of Western Lake Erie.

The relative positions of the different sections with respect to

intensity of pollution as indicated by the chemical data, particularly albuminoid ammonia, were: (1) Maumee Bay; (2) River Raisin; (3) Portage River; (4) Island; (5) Detroit River. In the lower parts of Maumee and Raisin Rivers and in small areas in the lake near the mouths of these rivers, pollution was sufficiently intense to make the chemical conditions harmful to aquatic organisms which would normally inhabit such areas. In the Portage River, Island, and Detroit River Sections there was no evidence of pollution of sufficient intensity to cause harmful chemical conditions.

The results and conclusions reviewed above refer to the period when the lake is free of ice. Determinations of oxygen, carbon dioxide, and pH, made under the ice near the west shore when the period of ice-closure was about three-fourths completed, indicate that chemical conditions there were little, if any, less favorable than those prevailing during the summer.

The available evidence, both direct and indirect, indicates that poisonous substances are not present in the lake in concentrations sufficient to affect aquatic organisms harmfully.

The final conclusion to be drawn from the chemical data is that pollution has had both harmful and helpful effects on chemical conditions in Western Lake Erie. The harmful effect has been the marked reduction in oxygen content of water discharged into the lake from Maumee and Raisin rivers. The helpful effect has been the addition to the lake water of large quantities of nutritive materials, which probably have made possible a great increase in the abundance of plankton organisms. It is probable that the harmful effect has been offset, largely if not entirely, by the helpful effect.

Phytoplankton

The horizontal distribution of the phytoplankton was not uniform in the Island Section. There was little evidence that some stations had consistently high counts and others consistently low counts. Indirect evidence from a comparison of seasonal distribution in the two years indicates that the lack of uniformity was not such as to invalidate a determination of average abundance for the area based on samples from several stations.

The vertical distribution was essentially uniform. Differences in abundance at different levels were found, but, in general they were not large and were not consistently of the same kind. That is, the greatest abundance may be found near the surface at one time, and near the bottom at another time.

Only in the Island Section was sampling continued long enough to trace the seasonal changes in abundance clearly. Nothing is known of the abundance in November, December, January, February, or March; the following summary is based on a study of the

remaining months of the year. Diatoms as a group had two maxima, one in spring and another in autumn. In 1929 the spring maximum came in early June; in 1930 it came in late May. Earlier appearance of the maximum in 1930 probably resulted from earlier warming of the water in that year as compared with 1929. In the autumn of 1929 the diatoms reached their greatest abundance in late October, but may have continued to increase for some time after the close of the sampling season. It seems probable that in 1930 the diatoms as a group reached their autumn maximum after the close of the sampling season in early October. Diatoms were more abundant in autumn than in spring of 1929; this may or may not have been the case in 1930. Greens had one maximum and this came in autumn (late September in both years). Blue-greens had one maximum and this coincided with the maximum of greens. Groups other than diatoms, greens, and blue-greens did not make important contributions to the abundance of phytoplankton.

In spring the phytoplankton was composed almost exclusively of diatoms. In summer all groups were rare. The autumn maximum was composed of large numbers of all three groups, but diatoms and blue-greens were more abundant than greens.

For comparable periods of time, the two years agreed closely with respect to (1) average abundance of phytoplankton groups, (2) times of changes in abundance, and (3) degree and direction of change. For the period late May—early October, the two-year averages, stated in thousands of units per liter, were as follows: diatoms, 90; greens, 38; and blue-greens, 58. The highest average counts in a period of two weeks (not necessarily the same period for all groups) were: diatoms, 261; greens, 128; and blue-greens, 203. The lowest were: diatoms, 14; greens, 0.5; and blue-greens, 0.5. The highest average count of all groups combined for a single period was 544, and the lowest 33.

The Island Section of Western Lake Erie is richer in plankton than Lake Erie east of that area, and richer than Lake St. Clair. Comparisons with Lake Mendota, a eutrophic lake, and Green Lake, an oligotrophic lake, on the basis of the dry weight of organic matter in the centrifuge plankton in autumn (and other considerations), show that Western Lake Erie stands between the two in richness. It probably stands nearer to Lake Mendota than to Green Lake. Since these two lakes are fairly typical of their classes, and since eutrophic lakes are generally rich and oligotrophic lakes generally poor, the Island Section of Western Lake Erie might be described as "moderately rich" in plankton.

Large and highly consistent inequalities in horizontal distribution exist in Western Lake Erie as a whole. For the months of July, August, and September of 1930, the average abundance per unit volume of water in the Detroit River Section was 1/4 of that in the Island Section; 1/11 of that in the Portage River Section;

1/16 of that in the River Raisin Section; and 1/26 of that in the Maumee Bay Section. The data do not permit such a definite statement of relative abundance for 1929. As far as comparisons can be made, they indicate that the relative positions of the sections were the same in both years (with one minor exception), but that differences in abundance were not as marked in 1929 as in 1930. The algae were distinctly more abundant in Maumee Bay and River Raisin Sections in 1930 than in 1929.

The most probable explanation of these differences in abundance between sections is as follows: The sections which are now especially abundant in plankton (Maumee Bay, River Raisin, Portage River Sections) were abundant in plankton under natural conditions. Shallowness of water is believed to have been the principal contributing factor in this richness, with the added factor, in the case of the Portage River Section, of the lacustrine character of the lower river. Superimposed upon this natural richness is the richness caused by the nutritive salts derived from domestic sewage. Detroit River Section is poor in plankton because the source of the river, Lake St. Clair, is poor in plankton, and not because of the destructive effect of poisonous chemicals derived from industrial wastes. There is little or no local increase of abundance resulting from domestic pollution in this section. The natural abundance of plankton in the Island Section has been increased as a result of pollution, by the eastward drift of organisms produced near the rivers, and by the use of the excess of nutritive salts. The relative positions of the different sections of the lake with respect to abundance of phytoplankton was the same as with respect to intensity of pollution as indicated by the content of albuminoid ammonia.

Zooplankton

The crustacea were not uniformly distributed in the Island Section, but there is no evidence that they were consistently abundant at certain stations and consistently rare at others. Comparisons of seasonal distribution of individual genera in 1929 and 1930 indicate that the lack of uniformity was not such as to invalidate a determination of average abundance in the section based on samples from several stations.

Vertical distribution was studied only during the hours of daylight, so that nothing is known regarding diurnal migrations. In the daytime the adult crustacea were usually rare at the surface and near the bottom, and were most abundant at some intermediate depth. Nauplii and rotifers appeared not to avoid the water near the surface, but were commonly concentrated at more than one level. There were numerous exceptions to any general rule regarding vertical distribution of the zooplankton organisms.

Only in the Island Section was sampling continued over a sufficiently long period to show seasonal distribution clearly. Nothing is known definitely regarding abundance in the months of December, January, February, and March, but there are reasons for believing that the crustacea are rare during that period. During the remaining months, the adult crustacea were rare in spring and autumn, and were most abundant in summer. In 1930 copepod larvae were most abundant in late spring, and probably the same was true in 1929.

The four most prominent genera of crustacea are Cyclops, Diaptomus, Daphnia, and Diaphanosoma. For the period late May—early October for the years 1929 and 1930, the mean counts per liter in the Island Section were as follows: Cyclops, 10; Diaptomus, 6; Daphnia, 4; Diaphanosoma, 1. The corresponding mean for the nauplii was 16 per liter. Comparisons of these figures with corresponding figures from a typical eutrophic lake and a typical oligotrophic lake show that the Island Section holds an intermediate position with respect to abundance of crustacea. Since eutrophic lakes are characteristically rich in plankton and oligotrophic lakes are poor, Western Lake Erie in the Island Section may be described as "moderately rich" in plankton crustacea.

Large and highly consistent inequalities in horizontal distribution exist in Western Lake Erie as a whole. For the months of July, August, and September of 1930, the mean number of crustacea in the Detroit River Section was 1/13 of that in the Island Section; 1/17 of that in the River Raisin Section; and 1/20 of that in the Maumee Bay Section. Differences of similar magnitude were found for about the same period of time in 1929. These differences in abundance of the plankton crustacea are believed to be dependent upon the amount of food available to them, for in 1930, and probably in 1929 also, the different sections just mentioned held the same positions with respect to abundance of phytoplankton as they did with respect to plankton crustacea. That is, the Maumee Bay Section was first in abundance of both kinds of plankton organisms, the River Raisin Section was second, the Island Section third, and the Detroit River Section fourth. The Portage River Section is not included in the list because it is represented by less adequate data.

It is believed that the observed differences in abundance and different sections are in part the result of natural conditions, and in part the result of pollution. In all probability, the increase of phytoplankton and organic detritus resulting from pollution has made possible an increase of the crustacea.

Bottom Organisms

Preliminary sampling showed that the characteristic organisms of clean mud bottom was the nymph of the burrowing mayfly, *Hexagenia.*

On bottom polluted by organic debris, this organism was largely or entirely replaced by tubificid worms of the genera *Limnodrilus* and *Tubifex*. In reaching the conclusions with regard to the extent and degree of pollution, the following criteria of pollution were employed. A mud bottom having less than 100 tubificid worms and more than 100 *Hexagenia* nymphs per square meter was considered to be free from pollution; a larger number of tubificids and smaller number of *Hexagenia* was regarded as evidence of pollution. Three degrees of pollution were recognized, based on the number of tubificids per square meter, as follows: Light pollution, 100-999; moderate pollution, 1000-5000; heavy pollution, more than 5000. On the other than mud bottom, only the tubificids were used as a criterion of pollution.

In the Island Section quantitative samples were taken only on mud bottom. Nymphs of the mayfly, *Hexagenia,* were more abundant than all other organisms combined. In 1929 the average number of *Hexagenia* for seven stations was 283 per square meter, which was 65 per cent of the total number of organisms. In 1930 the average number for five stations was 510 per square meter, which was 87 per cent of the total. Considering only the four stations sampled in both years, *Hexagenia* was about one and one-half times as abundant in 1930 as in 1929. In both years most of the sampling was done after the period of emergence of the insects. Very probably sampling throughout the year would have shown much higher counts of *Hexagenia.* Tubificid worms were rare in both years. Areas with mud bottom in the Island Section may be regarded as free from pollution by organic debris.

The average dry weight of *Hexagenia* nymphs for the two years was 43.2 Kilograms per hectare (38.5 pounds per acre). This figure is close to that for all organisms in a similar zone of Lake Mendota; it is below that of Lake Wawasee, but above that of three other North American lakes. Thus, the Island Section compares favorably with inland lakes with respect to the weight of bottom organisms per unit of area.

There was no evidence of pollution of the bottom in the Portage River Section near the mouth of the river. Definite evidence of pollution was found near the mouths of the rivers in the Maumee Bay, River Raisin, and Detroit River Sections. The estimated areas of the zones of pollution were as follows: Heavy pollution, 25.2 square kilometers (9.7 square miles); moderate pollution, 46.3 square kilometers (17.9 square miles); light pollution, 191.4 square kilometers (73.9 square miles). The total area in the three zones of pollution was 262.9 square kilometers (101.5 square miles), or 7.7 per cent of the water area of Western Lake Erie exclusive of Sandusky Bay (Figure 2). Of the total area in the three zones of pollution, 72.8 per cent fell within the zone of light pollution, and an unknown but considerable part of this zone was free of organic debris.

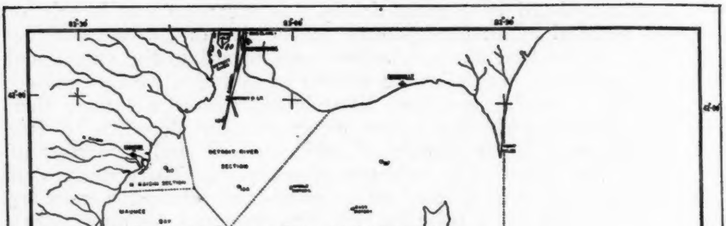

Figure 2. Western Lake Erie, showing the estimated areas of the zones of light, moderate and heavy pollution.

Effect of Pollution on the Fishery

The extent and degree of pollution in Western Lake Erie has been determined with some degree of exactness, but interpretation of the facts in terms of the effects on the fishery must be based largely on conjecture. Some of the effects of pollution are obviously harmful to fishes and hence to the fishery, while others are clearly advantageous. However, there are no standards by which they can be measured and compared quantitatively, to determine the residual effect on the fishery. No attempt will be made here to enter into a detailed discussion of the problem. Briefly stated, the conclusions reached are as follows. Conditions in the lower parts of Maumee and Raisin Rivers, and in small areas of the lake near their mouths, have been made unfavorable or prohibitive to all except the most tolerant fishes by reason of the low content of oxygen and high content of free carbon dioxide. In addition, considerable areas of the bottom near Maumee, Raisin and Detroit Rivers have been rendered unfit for spawning purposes by the deposition of organic debris, but it should be recognized that a large part of the polluted area probably never was suitable for spawning because of the deposition of silt. These harmful results of pollution have been offset, partially or wholly, by the increase in plankton organisms which are used as food by all young fishes and the adults of certain species. In view of the tendency of the harmful and

helpful effects to balance each other, it seems highly improbable that pollution in the western part of the lake has been the controlling factor in the depletion of the fishery of Lake Erie.

Discussion

MR. MARKUS: With regard to your conclusion on the question of pollution, that the harmful results are offset by the increase in the organisms present, such as phytoplankton and zooplankton, but that pollution affects adversely the spawning grounds of the fishes, does it not follow that if the spawning grounds are disturbed there would be no fish to feed on that increased supply of organic matter brought about by the pollution?

MR. TIDD: I pointed out that there is only a very small area of heavily polluted bottom, and that is around the mouths of these creeks and tributary streams. No doubt the albuminoid ammonia content of the water has been increased in all of these sections as the result of pollution. If that is so, it would naturally increase the food content of the water for the larval fish and also for the adults of certain species. Does that answer your question?

MR. MARKUS: The thing I was questioning is this: if that pollution is coming in there is a new bottom fauna taking the place of the fauna that was present before pollution came in, therefore the fish life would have to be changed in order to adapt itself to that situation. That means a new bottom fauna, and then, to follow that, we would have to have a new fish fauna that would adapt itself to the changed conditions.

MR. WICKLIFF: There is another point to consider: the mouths of these streams contain a considerable amount of silt which is carried down stream from their drainage areas; the silt is deposited at the mouths and for a distance into the lake. Possibly these areas never were good spawning grounds because of the deposition of the silt; and also the total amount of bottom occupied by this silt is small when compared with the number of square miles of spawning grounds suitable for the species in the western end of Lake Erie.

MR. CULLER: In the old days the best spawning grounds for whitefish were from Port Clinton north and west to Monroe. About twenty years ago Monroe was one of our most important egg-collecting stations. After the industrial waste began to be apparent, the fisheries around Stoney Point and Put-in-Bay began to fall off. Since the industrial plants have closed, my reports from Put-in-Bay indicate that the fish are working back up into that section. If the industrial plants start to operate again in full force, the chances are that these fish will move from that point. I know this, that in our Toledo field the percentage of fertility of the eggs we used to get at Put-in-Bay was far lower than in any other section, and I ascribed that to the fact they were using water that was polluted by industrial waste.

MR. TIDD: At Put-in-Bay?

MR. CULLER: The eggs received from the Toledo field. The best eggs that we get are from the vicinity of Port Clinton, where there is less industrial

waste. Don't you think the reason for the lack of evidence of pollution affecting the fisheries in the western end of Lake Erie, since your results were obtained in 1930, is the fact that the industrial plants have closed?

MR. TIDD: The period was 1926 to 1930—five years.

MR. CULLER: I was referring to your figures for 1930.

MR. TIDD: The results for the other years were quite similar to these.

MR. WICKLIFF: Partly to answer Mr. Culler, may I point out that we have done some experimental work on the resistance of yellow pike-perch eggs —pickerel, they call them in the wstern end of Lake Erie—and whitefish eggs. The whitefish egg is very resistant to environmental conditions, while the pickerel egg apparently is not. It is true that at the present time we obtain most of our whitefish eggs from Kellys Island and the Bass Island district, but the pike perch egg, which is more susceptible to environmental conditions, we do not obtain to any extent from the island district; these eggs are taken primarily west of the Bass Islands and particularly in the vicinity of where the Toledo fishermen fish. During the spring and summer of 1928 we caught over 20,000 baby fish in 225 hauls of the meter net. Each haul of the net was approximately one-half mile, and the area covered was west of Kellys Island. On June 29, 1929, we made five surface hauls near the mouth of the Portage river and over 18,000 baby fish were taken. Up to the present time Professor T. L. Hankinson, State Normal College, Ypsilanti, Michigan, has identified twenty-three species taken in meter nets. Our meter net, seine and Peterson trawl catches show a definite concentration along the Ohio and Michigan shores where pollution would be at its worst. A number of these baby fish were yellow pike-perch and pollution as a factor in fish depletion is not as serious as it was at first thought to be. Baby whitefish were collected primarily over a rock bottom, but baby pike-perch were taken largely over a sand or hard clay bottom. This is a complicated problem, but I think the point is well brought out in the paper that the total number of square miles of polluted area is not as great as was thought in the first place. We certainly cannot say that pollution is a major factor in the decrease in fish life. In Maumee Bay I have taken carp eggs in different stages of development that were attached to vegetation, brought them back and hatched them in the laboratory. Even where the bottom has been destroyed for incubating fish eggs such eggs in the vegetation above the bottom may hatch.

DR. HUBBS: These two investigators ought to be complimented upon their approach to this problem. Many scientific investigators of pollution problems have felt they were necessarily crusaders attacking a great evil. Unquestionably much correction needs to be done, but I think we need a rational approach to this problem in an investigative way as well as the crusading—which, of course, has its advantages, because most people cannot be stirred by scientific facts unless some crusading is thrown in. This possibility of pollution being beneficial to fish life is something that a good many people look upon as almost a sacrilegious idea, but almost every fish culturist in these days knows and appreciates the value of polluting

his fish ponds in order to increase the production, because that is what he does when he fertilizes them. It is, as I say, notable that this problem should be approached in this rational way.

One point which was not brought out, and which is not usually brought out in thinking about pollution, is, that if organic pollution and sanitary sewage, which is akin to industrial pollution, are treated in a satisfactory fashion, the fertilizing qualities in these materials are retained and put in the water in a better fixed and more appropriate form for the plants to use and in that way contribute to the building up of the fish life. A proper treatment of the sewage of all these cities by sedimentation plus oxygenation would produce a sewage which would benefit the lake by increasing the fertility, and at the same time would decrease the harmful effects.

On top of the harmful effects of sewage, I think perhaps even more important is the harmful effect of soil erosion and silting off the mouths of these rivers. Even if all that pollution had been removed many years ago it is questionable whether those areas would have been very much different from what they are now. The extremely rich washings from the farm fields of Michigan and Ohio into Lake Erie have unquestionably caused a tremendous deposit of silt off these waters, and I believe their effects would still be present even if that pollution had not been there. In Iowa, for instance, the effects of pollution in the interior lakes result in phenomenal growths of algae which cause a loss of fish. These effects are felt in lakes which receive absolutely no pollution as well as in lakes which are polluted by cities on the borders of those lakes. In other words, the washings from the fertile lowland fields are the same sort of material that occurs in the sewage, so that almost the same effect is produced in either case.

Mr. Culler: Mr. Wickliff compares the carp egg with the egg of the whitefish, but the carp egg is deposited on plant life possibly a foot or two feet above the bottom, while the whitefish and pike-perch eggs are deposited on the bottom and naturally come in contact with the sludge or offensive material that may be on the bottom.

Mr. Wickliff: I think the point is well taken. What I had in mind was that, as Dr. Hubbs has stated, erosion has caused the deposition of silt off the mouths of these streams, and possibly at no time was spawning very heavy, at least while the deposition of silt occurred; but just above the deposit of silt, where we find adhesive eggs like those of carp and goldfish, the conditions may be suitable.

Just one other point, and that is the number of nets in the western end of the lake. In 1885 the Bureau of Fisheries published a map of Lake Erie showing the total number of nets in the lake. We now have maps for the Ohio side showing the total number of nets during the inspections for 1932 and 1933, and the contrast between the small number in 1885 and the numbers in 1932 and 1933 is extremely interesting and opens a new problem.

Mr. Adams: I would like to add one suggestion to the discussion. he men who have charge of this work in the several states are constantly ham-

mered on this question of pollution. In every state there are two agencies, as a rule, that deal with the subject, the State Department of Public Health and the Conservation Department. These departments approach the subject from entirely different directions. In practically every state the departments of public health are interested in these waters only from the point of view of public health, and frequently when we have called in the state department of public health to assist us in handling a problem, they pursue the subject no further when they find that a given water is suitable and comes up to the standards of their department from the point of view of the public health. There are thousands of instances where waters pass the test of the state public health services that are not in any sense fit for fish life. To be specific, water that has been chlorinated, although satisfactory for the use of the public, would be a total loss so far as fish cultural purposes are concerned. When we come to the conservation part of it, as the doctor has pointed out, the general public approach this subject from a crusader's point of view and want to have the trade wastes or other wastes taken out of those waters whether or not they are injurious to fish life. It sounds like rank heresy on the part of any of us men to say: It is true that that water is polluted, but as a matter of fact, it is all right for fish life. I have had to contend with this from the angle of the effect of pollution on shellfish eggs. Around the boundaries of some of the larger rivers, particularly on the Atlantic coast, the irony of the thing is that shellfish grow more freely in these polluted areas than they do in any other waters. Two specific instances come to my mind—the Merrimac river in the State of Massachusetts, and the western side of Buzzards Bay, where large areas are contaminated by the trade waste and other wastes from the city of New Bedford. A third instance is the polluted areas of Jamaica Bay, along the western end of Long Island. In these areas shellfish grow more abundantly than they grow anywhere else. We have found in the past that by collecting these shellfish, particularly the hard-shelled clam or quahaug, and transporting them and bedding them down in clean salt-water—depending on the time of year, the temperature of the water, and how active these fish are in syphoning the water and other food products—in a comparatively short time they will purify themselves.

It is very difficult to bring home to the public the fact that these things are as they are. Within the last year and a half I have been very hard pressed in regard to the effluent of the roundhouse of a railroad company being allowed to pass into a tributary of one of our largest rivers. I had one of our biologists make a careful test of that water, and before we got through we found that while this material had fouled the bathing beaches and gummed up the boats in that region, with the exception of perhaps a thousand feet from where the pollution went into the tributary stream it had practically no effect on the fish life in that area. I think it is a splendid thing that we should have had this discussion today in regard to the western end of Lake Erie, and the frank statements that you men who are engaged in the scientific end of this work

have made here in regard to pollution, because we are starting now to get away from the hue and cry of the public and are working this thing out on a scientific basis. I cannot begin to impress upon you the value of this research; you are giving us the real fundamentals that will enable us to deal with the general public and that will guide us in our work when it comes to balancing the equities in some of these extremely difficult matters.

Mr. Culler: The question is one of long standing. Back in 1873 those who had to do with the matter deplored the fact that pollution was taking such a heavy toll of our fisheries, and were wondering how to control it. From 1873 to 1933 is a far cry.

Mr. Adams: I can remember when I came to New York to work how dire were the predictions with regard to the effects of pollution; the view was expressed that it would be only a few years before the last shad would be caught out of the Hudson river. As a matter of fact, pollution has increased in the Hudson river, but the run of shad is increasing every year.

POPULATIONS OF HERRING IN THE COASTAL WATERS OF BRITISH COLUMBIA

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The Pacific herring (*Clupea pallasii* Cuvier and Valenciennes) is present in great abundance along the west coast of North America from Southern California to Alaska. Since the beginning of the present century, two great herring fisheries have developed, one in Alaska and the other in British Columbia. The total quantity of fish removed from the waters each year is enormous. The British Columbia fishery alone has utilized in recent years from 50,000 to 100,000 tons annually. The immediate goal of herring investigations which have been conducted for several years in Alaska and more recently in British Columbia, is to determine the effect of this tremendous drain upon the stock.

The extent of migration of a species of commercial fish has an extremely important bearing on the problems of fluctuation, depletion, and administration of the fishery. If schools of herring migrate indiscriminately up and down the coast, promiscuous intermingling of the stock will take place; overfishing in one locality will exert a drain on the fishery as a whole and ultimately will result in a general depletion. If, on the other hand, the extent of migration is limited, intermingling on a large scale will not take place; the schools in each locality will tend to form 'races' or local populations; overfishing in one area will not drain the stock as a whole, but will result in a local depletion.

As it is not feasible to tag herring, the extent of migration must be investigated by a statistical analysis of socalled 'racial' characters —various counts and measurements made on a large number of individuals. If the total stock of herring belongs to one large population, the mean value of these characters in each locality will not vary to a significant extent. If, however, local populations occur, certain slight differences in physical, chemical, or food conditions may cause small but significant differences in the average counts and measurements which may be detected with the help of standard statistical procedures. By far the most important character used in racial work, and the only one discussed in this paper, is the mean vertebral count. The number of vertebrae in the vertebral column is fixed a short period after hatching and is not influenced therefore, by subsequent changes in environmental conditions.

Rounsefell (1930) has demonstrated that there is a gradual increase in the mean vertebral count of herring from about 50.7 at San Diego, California, to about 53.2 in the Alaska peninsula. The mean for southern British Columbia (51.8) was found to be about mid-way between these two extremes, the value correspond-

ing with its geographical location. In a later publication, Rounsefell and Dahlgren (1932) show that the mean vertebral count varies inversely with the temperature of the water during the period in which the eggs were spawned and developed. It may be assumed, therefore, that the increase in vertebral count with latitude along the coast is the result of a progressive decrease to the northward in temperature conditions of the inshore winters in the late winter and spring months when spawning and early development takes place. The vertebral gradation proves that there is no extensive migration of schools of herring along the coast for, if such did occur, the gradation would be obliterated by intermingling. It therefore follows that the herring population of British Columbia as a whole, is distinct from that of California to the south and from that of Alaska to the north.

The Alaskan investigators have shown, in addition, that not only is the population of herring in Alaska distinct from that to the south but that it may be sub-divided into a series of local populations extending from southern Alaska to the Aleutian islands. As only a few particular localities in British Columbia, those of easiest access to the markets, are fished intensively, it is of prime importance to determine if a similar condition exists within the waters of this province. In other words, it is necessary to determine whether or not migration and intermingling is so slight that the total population may be divided into several smaller units, each of which is distinct, and any one of which might be materially reduced or even obliterated by overfishing.

In the fall, winter and spring months of 1931-32 and 1932-33, samples of the commercial catch were obtained from localities extending from Barkley sound, on the west coast of Vancouver island, to Pearl harbour, near Prince Rupert. The geographical positions of these localities are shown in figure 1. Various external measurements and counts were made on the fish, following which they were placed in pans and partially cooked. It was then possible to remove the vertebral columns intact and to count the number of vertebrae between, but not including, the basi-occipital and hypural bones. To insure absolute accuracy the counts were repeated at least once; vertebral columns showing abnormalities were discarded.

The latitude, the number of specimens examined, and the mean vertebral count with its probable error, are given for each locality in table I. It is at once apparent from the results that differences in vertebral counts occur between the various localities. In 1931-32 the difference of 0.52 vertebrae between Barkley sound and Pearl harbour was 11 times its probable error; in 1932-33 the difference of 0.40 vertebrae between these two localities was 13 times its probable error. This is statistical proof of the significance of the difference in count between Barkley sound and Pearl harbour. It

demonstrates conclusively that migration is limited and that the populations in each of these areas, separated by a distance of 450 miles, are isolated from one another.

TABLE I

Mean Vertebral Counts of Herring in Various Localities in British Columbia

Locality	Latitude	1931-32 Mean Vert. Count	1931-32 No. of Specimens	1931-32 P.E.	1932-33 Mean Vert. Count	1932-33 No. of Specimens	1932-33 P.E.
Barkley Sound	48°55′	51.78	143	0.036	51.85	804	0.015
Sydney Inlet	49°25′	51.84	333	0.024	51.86	371	0.024
Nootka Sound	49°42′	51.92	326	0.026	51.95	381	0.022
Kyuquot Sound	50° 6′	51.93	286	0.026	51.93	379	0.021
Quatsino Sound	50°29′	—	—	—	51.97	232	0.028
Bella Bella	52°15′	—	—	—	52.08	307	0.026
Jap Inlet	54° 3′	52.24	196	0.033	52.23	246	0.027
Pearl Harbour	54°32′	52.30	198	0.032	52.25	248	0.027

A further study of the table and an examination of figure 2 reveals that within the waters of British Columbia, with minor exceptions, there is a gradation in vertebral count with latitude. This fact is of utmost importance. It indicates that, not only are herring from the northern waters of the province distinct from those in the southern portion of Vancouver island, but that a series of local populations exists between the two extremes. While in most cases, the differences between adjacent localities are so small that a larger number of specimens from each would be necessary to establish their statistical significance, nevertheless, the fact that a gradation in vertebral count has persisted for two years is rather conclusive proof that intermingling is so slight that the population of each fishing area is essentially localized and must therefore be regarded as a separate unit.

The commercial catch of herring includes several age groups or year classes. Rounsefell and Dahlgren, in demonstrating the inverse relationship between mean vertebral count and temperature, showed that in one locality the vertebral count of each year class would vary from year to year according to general spring temperature conditions. However, the mean vertebral count of a total sample may be taken as a running average of the mean counts of its year class components and therefore, as representing average conditions over a period of several years.

The evidence offered by vertebral counts of the localization of the runs in most localities has been largely substantiated by a critical examination of other racial characters. It therefore follows that intensive fishing in one area may result in a local depletion. It is evident that future exploitation should be regulated by government administration to avoid this possiblity. Fishing activities must be distributed throughout all localities and must be limited according to the size of the runs and the degree of exploitation which each run will withstand without endangering its perpetuity.

SUMMARY

The extent of migration of schools of herring has a fundamental bearing on the problems of depletion, fluctuation, and administration of the fishery. A study of vertebral counts of samples of herring from various localities in British Columbia shows that the general gradation of mean vertebral count with latitude along the west coast of North America persists within the waters of the province. This indicates that migration and intermingling is so limited that the herring in each fishing area in British Columbia tend to form local populations. It therefore follows that the intensity of fishing effort in each locality must be regulated to avoid local depletion of the run.

LITERATURE CITED

Rounsefell, G. A.

1930—Contribution to the biology of the Pacific herring, *Clupea pallasii,* and the condition of the fishery in Alaska. Bull. U. S. Bureau of Fisheries, Vol. 45, Doc. No. 1080, 1929.

Rounsefell, G. A., and Dahlgren, E. H.

1932—Fluctuations in the supply of herring, *Clupea pallasii,* in Prince William Sound, Alaska. Bull. U. S. Bureau of Fisheries, Vol. 47, Bull. No. 9.

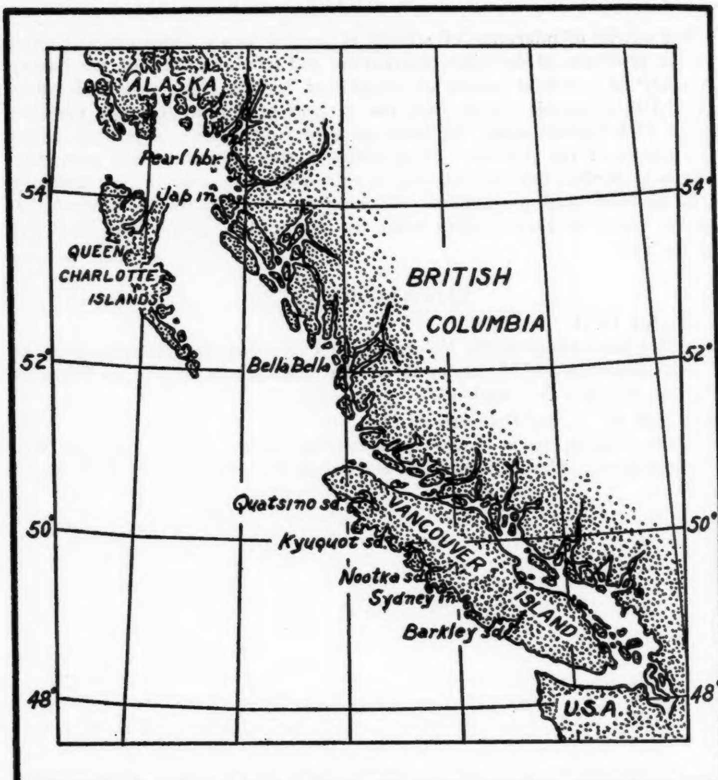

Figure 1.—Map showing the position of localities from which samples of herring were obtained for vertebral studies.

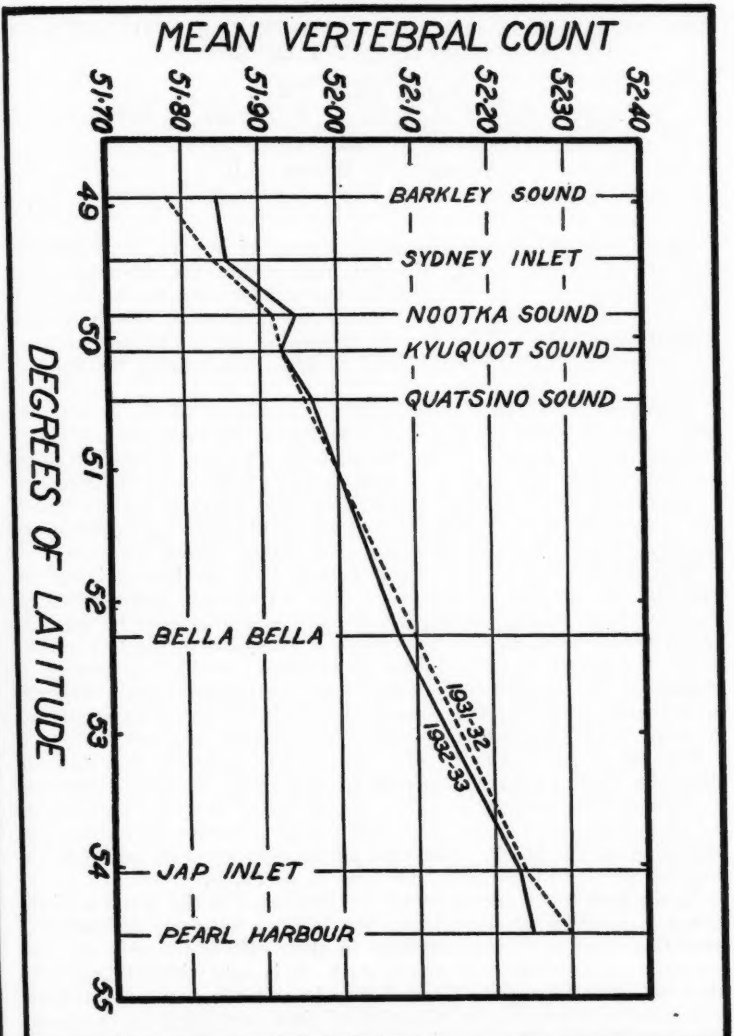

Figure 2.—Diagram illustrating the gradation of mean vertebral count with latitude in 1931-32 and 1932-33.

METHODS FOR THE INVESTIGATION OF THE STATISTICS OF THE COMMERCIAL FISHERIES OF THE GREAT LAKES*

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The Great Lakes are the chief source of supply of freshwater fish in the United States. For this reason they are subjected to an increasingly heavy fishery, and for the same reason the maintenance of their waters at the point of maximum production efficiency is of primary importance. Just how to determine and maintain that point of maximum efficiency is the chief problem confronting the fisheries today.

Past experiences have given repeated examples of the dire results which follow upon the ruthless exploitation of even the seemingly inexhaustible fisheries. The sturgeon has passed from the status of being a nuisance to that of being a rarity; the cisco of Lake Erie is no longer of commercial importance; and today in certain waters the chub bids fair to suffer a like fate. Still other forms, while not approaching extinction, show signs of rather severe depletion.

The rehabilitation of a ruined fishery is at its best a laborious, troublesome, and drawn out task. Nor is there any certainty that a commercially extinct species can by any measures ever be returned to its former condition of abundance. The sane method of protection of fisheries consists in the prevention, not the remedying of disaster. The catastrophes which have overtaken certain fisheries in the past might have been averted had their impending occurrence been realized early and precautionary measures adopted.

The future of the Great Lakes fisheries demands the prevention of disasters such as have occurred in the past. If the commercial extinction of a species is to be avoided there must be some means of measuring its changes in abundance, of detecting any dangerous depletion of the stock. For this purpose an accurate and comprehensive system of fisheries statistics is necessary.

In the past those persons who are interested in the welfare of the Great Lake fisheries have found the lack of adequate and accurate statistical data a severe handicap in their efforts towards the conservation and maintenance of the stock. It is only within recent years that the states along the Great Lakes have made any move towards a detailed and systematic collection of data pertaining to their commercial fisheries. In some instances these moves have unfortunately

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proved abortive and few data of real value have been accrued. In others the state officials have prosecuted the collection of statistics with such diligence that the data they have collected represent, for practical purposes, a complete record of the commercial fishing operations in the waters under their jurisdiction.

The state of Michigan has been a pioneer among the Great Lakes states in the matter of the systematic collection of fisheries statistics. Since September, 1927, they have required the submission of a monthly report from each licensed fisherman. During 1927 and 1928 the set of returns was by no means complete. Further, the inexperience of the fishermen in filling out the reports was such that many of them were of little use for statistical study. It was also found necessary in the earlier stages of the work to make certain changes in the arrangement and content of the original report sheets. Since the beginning of 1929, however, there has been a rigid enforcement of the rule which requires the regular submission of reports, and reports which were not made out properly were returned to their senders for correction. As a result, for the past four and one-half years there has been accumulated a highly reliable mass of information on the statistics of the commercial fisheries of the state of Michigan. These data cover the greatest period of time and the greatest diversity of gear and of fishing conditions of any similar materials available with respect to the Great Lakes fisheries. For these reasons they are being used as the basis of the Bureau's present investigation of the statistics of the Great Lakes fisheries. It is hoped that their study may lead to the development and perfection of standardized methods applicable to all Great Lakes fisheries, and that ultimately all the Great Lakes states will adopt a uniform method for the collection and analysis of much needed data relative to the statistics of their fisheries. The bureau acknowledges its indebtedness to the Michigan Department of Conservation for this invaluable source of material, and recognizes particularly the untiring efforts of the Honorable William H. Loutit, Chairman of the Department of Conservation, and Mr. Fred Westerman, in charge of the Fish Division, who have made such an efficient collection of data possible.

The monthly report submitted by each licensed Michigan fisherman contains a daily record of the kind and amount of gear lifted, the length of time over which it has fished, the location of the fishing grounds, and the catch in pounds for each species. To avoid confusion it is required that a separate report be filed for each type of gear fished.

For purposes of analysis of the statistical data the various lakes under the jurisdiction of the State of Michigan have been divided into districts. There are eleven districts in Lake Michigan, seven in Superior, six in Huron, one in St. Clair, and one in Erie. It has been attempted to make these districts the most natural divisions

of the fishing grounds possible. . Thus it is possible to study the various areas within the lake separately, and a simple summation provides the data for the entire lake.

The work of actual analysis of the statistics has only begun. Up to the present time the chief concern has been the development of methods of procedure. The nature of the Great Lakes fisheries is such that many of the methods ordinarily used in the treatment of fisheries statistics are not applicable here. The marine fisheries that have been subjected to detailed statistical studies have been unit fisheries, that is, fisheries in which the catch is comprised of a single important species. In the Great Lakes the hook fishery for trout is the only unit fishery. In other types of gear the catch is regularly composed of several important species, and each species is taken regularly by several types of gear. These circumstances introduce a complexity which requires the development of special methods adapted to the proper study of the special problems which the Great Lakes fisheries statistics present. It is the purpose of this article to call attention to certain of the peculiarities and problems connected with the study of the Great Lakes statistics, and to describe the methods by which it is proposed to obtain information bearing on them. The nature of these problems will appear in the following discussions of the methods of analysis of yield, effort, and yield in relation to effort. Almost all the illustrations will be drawn from District I of Lake Huron. This district comprises the most northerly portion of the aforementioned lake, and its limits are defined as follows: Entire area west of a line drawn from Drummond Island across the lake to and including Rogers City, Presque Isle County.

Yield: The yield of the fishery is considered from the following standpoints:

A. Annual yield:

(1) Total annual production by species (Table 1).

(2) Total annual production by gear (Table 2).

(3) Total annual production by species for each type of gear. (See Table 3, production of 4½" mesh gill net, as an example).

B. Yield within a single year:

(1) Total monthly production by species (Table 4).

(2) Monthly production by species for each type of gear. (See Table 5, monthly production of pound nets, as an example).

C. Yield for a single species:

(1) Annual catch. (See Table 6, annual whitefish catch, as an example).

(2) Monthly catch in each type of gear. (See Table 7, monthly whitefish catch, as an example).

In so far as yield in the above illustrations is concerned, our method does not differ from those employed elsewhere.

Effort: It is in relation to the study of fishing effort that the

special nature of the Great Lakes fisheries becomes most apparent. The fishing of the 2¾" mesh gill net will serve well as an illustration. With this type of gear there exist two distinct fisheries—the shallow water fishery for perch, herring, menominees, and other shoal water fish, and the deep water fishery for chubs. The two fisheries do not overlap. A gang of 2¾" mesh nets set in shallow water will take shallow water forms but will capture no chubs. The same nets set in deep water will take chubs (and small trout) but will capture none of the shallow water forms. It is obvious that a tabulation of the fishing effort exerted for the capture of chubs should not include the effort represented by the lifts of 2¾" mesh gill nets which were set in shallow water. Nor should the effort listed for the capture of perch, herring, and other shallow water forms include the effort represented by the 2¾" mesh gill nets which were fished in deep water, and which took only chubs and small trout. In spite of the identity of type of gear used the shallow water and deep water fisheries with the small-mesh gill net are completely distinct and must be considered separately. Almost every type of gear offers similar examples of efforts which have been exerted in quite different directions, and thus represent distinct fisheries.

It can be seen that a discriminating analysis of the Great Lakes fisheries statistics requires a separate listing of the effort exerted for the capture of each species. To achieve this end we have made the following definition of effective effort: *Effective fishing effort with respect to a given species is effort which has resulted in the capture of any quantity of that species.* The use of effective fishing effort is intended as a means of distributing effort according to the direction in which it has been exerted, and not as an elimination of fishing failures. As a matter of fact the original report sheets offer few examples of a failure of any gear to take at least a few of a species which is ordinarily to be found on the grounds upon which that gear was set. A decrease in the general population is reflected in generally smaller catches rather than in a notable increase in the number of failures. On the whole the tendency towards shoaling in the Great Lakes fishes is not sufficiently great to make the fishery a hit and miss affair. It is this fact which makes the use of effective effort valid.

The study of effort in a unit fishery is a comparatively simple affair, for here *effective* and *total* effort are identical quantities. For example, in most regions of the Great Lakes every hook lifted can be considered to have fished for trout. As an example of a similar situation in the marine fisheries we may consider the trawl fishery for plaice, where it is certain that every hour's trawling actually represents effort for the capture of plaice. It should be mentioned, however, that a study of effort in plaice fishing would hardly in-

clude the effort represented by the haul of trawls used in the herring fishery.

For an illustration of the tabulation of the effort of a single type of fishing gear over the period of a year, consult Table 8. To show the significance of the data consider the month of May. During this month there were 310 pound net lifts (total effort). Trout occurred in 288 of these lifts, whitefish in 300, herring in three, and yellow pike in 17 (effective efforts). Such a separation is justifiable as the nature of the catch of a pound net depends quite closely upon the locality in which it was set. A pound net in one locality may take large catches of whitefish and no herring. The same net, if it were moved to another location, might take large catches of herring and no whitefish.

In many instances the study of fishing intensity and of changes in abundance requires the introduction of the time element into the analysis of the data relative to fishing effort. As an illustration of this point consider the relative fishing efforts of two lifts 25,000 feet of gill net, the first of which has been in the water two days while the second has been set four days. On the basis of the amount of gear lifted they represent equal amounts of fishing effort. Actually the nets of the second lift have fished twice as much as those of the rest. Within a single geographical area the average amount of time over which a particular type of gear is allowed to fish before it is lifted does not vary greatly from year to year. There is, however, within the same geographic region, a considerable variation in the fishing time of certain types of gear from one time of the year to another. Further, different regions show consistent annual and seasonal differences in the fishing time of the same type of gears, and different types of gear have different characteristic fishing times (See bottom of Table 10). Because of these facts it is necessary that time be considered in the study of seasonal changes in abundance within an area and in the comparison of two separated areas. Two examples should be sufficient illustration.

To show the importance of time in the study of seasonal changes in abundance, assume that it is desired to compare the abundance of trout on the gill net fishing grounds of District I, Lake Huron, in the months of April and October, 1930. The catch in April was 11.0 pounds for each 1,000 feet of large mesh net lifted. In October the catch was 34.8 pounds for each lift of 1,000 feet. From these figures it might be inferred that trout were approximately 3.2 times as abundant in October as in April. If, however, the effort is considered in terms of the action of 1,000 feet of net over the period of one day the production figures become: April—3.0 pounds; October—19.1 pounds, and the data indicate that on the gill net grounds trout were 6.4, not 3.2 times more abundant in October than in April. The discrepancy finds its origin in the fact

that in April gill nets fished for trout were in the water approximately four days before lifting, and in October only two days.

Similarly, time is of importance in comparisons which involve geographically separated areas as may be seen in the comparison of the fishing efficiency of pound nets in Districts I and III, Lake Huron, during the 1930 season. The average lifts in pounds of pound nets were: District I—151 pounds; District III—314 pounds. From these data it would appear that the District III pound nets were 2.08 times as effective as those of District I. The actual catches of pound nets per night of fishing were: District I—55.9 pounds; District III—152.3 pounds. Thus it may be seen that the District III pound nets were 2.72, not 2.08, times as effective as those of District I. The reason for the difference is that the fishing time of pound nets in District I was 2.7 days while in District III it was 2.1 days.

The time element does not enter into the study of the seine fishery, and it must remain an undetermined factor in the insignificant hand line and dip net fisheries.

In connection with the study of fishing effort the following terms have been defined:

1. **Net lift: The effort represented by the lift of one net. (Trap, pound, fyke, hoop).**
2. **Net night: The fishing effort of one net over the period of one day. (Trap, pound, fyke, hoop). The number of nights out is taken as the measure of time.**
3. **Foot lift: The effort represented by the lift of one foot of gill net.**
4. **Foot night: The fishing effort of one foot of gill net over the period of one day. The actual units used are (3) 1000 foot lifts and (4) 1000 foot nights.**
5. **Hook lift: The effort represented by the lift of one hook.**
6. **Hook night: The fishing effort of one hook over the period of one day. The actual units used are (5) 1000 hook lifts and (6) 1000 hook nights.**
7. **Rod-haul: The effort represented by the haul of one rod of seine. The unit used is 100 rod hauls.**

Fishing effort measured without reference to fishing time, and fishing effort in which the time element has been introduced are both real and reliable quantities. They differ with respect to the point of view from which the fishery is being considered. The former measure of effort represents the actual amount of energy which the fisherman exerts. The latter is a measure of the actual intensity of fishing. For the purpose of distinguishing the two types of effort we define that effort which does not consider the time element merely as *fishing effort* and that effort which takes time into consideration as *fishing intensity*. In the seine fishery, of course, the two types are identical. Tables 9 and 10 show total fishing effort and total fishing intensity in District I for each of the years 1929-1932.

The yield in relation to the amount of fishing can be expressed as *yield per unit effort* or as *yield per unit intensity*. The former measures the return to the fisherman per unit amount of labor expended. The latter is a measure of the abundance of fish on the fishing grounds. Since effort can be considered on the basis of total effort and effective effort (the same applies to intensity) the unit yield can be expressed by any one of four quantities. As an illustration consider the yield of trout in relation to the amount of fishing in the year 1931 (Table 11). With respect to trap nets, for example, the data signify as follows: (1) In trap nets which caught trout the average lift was 22.41 pounds of trout (yield per unit effective effort). (2) For every trap net lifted in District I in 1931 there were captured 7.86 pounds of trout (yield per unit total effort). (3) Each net which captured trout took an average of 5.77 pounds of that fish each night it fished (yield per unit effective intensity). (4) For a day's fishing of every trap net in the district in 1931 there were captured 1.56 pounds of trout (yield per unit total intensity). The implications with respect to the other types of gear are similar. The units of effort and intensity have already been defined (p. 10).

For a second example of the tabulation of the different types of unit yield consult Table 12, which shows a tabulation of yield in relation to the amount of fishing for the various species taken in the pound nets of District I, 1932. The sums of the separate yields, catch per lift and catch per night as based on total fishing gear, represent the average catch in pounds per lift and average catch in pounds per night (all species) for all pound nets of the district (last column, Table 12). These average catches per unit effort and per unit intensity are shown in Table 13 for all types of gear over the four-year period (1929-1932).

The study of the variation in unit yield of the trap nets (see Table 13) furnishes an excellent example of the importance of listing effort and intensity both as total quantities and as to their effective distribution with respect to the different species. It will be noticed that in 1930 the average lift in pounds for trap nets was nearly double that of the preceding year. In 1931 the average lift increased still more, but fell off considerably in 1932. The changes in yield per unit intensity followed a similar trend. From our acquaintance with the fishery we know that these great annual fluctuations in the average yield of trap nets do not represent correspondingly large changes in abundance of fish on the fishing grounds, but that they resulted from the introduction into the fishery of a new type of trap net, the deep trap, or "sub." Prior to 1930 practically all trap nets fished in northern Lake Huron were "shallow traps." Their catch consisted chiefly of suckers, yellow pike, perch, and other shallow water species. In 1930, however, the deep trap or "sub" came into general use for the capture of white-

fish (deep traps ordinarily take small but important catches of trout). The introduction of the deep trap net meant the establishment of a new fishery, a fishery quite different from the shallow trap net fishery. Since the fisherman's original reports do not distinguish between deep and shallow traps it was found necessary in order to separate the two fisheries to turn to the study of the effective fishing efforts of the trap nets.

The consideration of the fishing efforts of trap nets was centered on the most important species of each type. In Huron, District I these are in the shallow trap the sucker, and in the deep trap the whitefish and the trout. Table 14 shows the percentage of trap nets lifted which were effective in the taking of whitefish, suckers, and trout in each of the years, 1929 to 1932. It will be seen that the sum of the percentages for whitefish and suckers in each year approximates 100 per cent quite closely. Since in 1929, when deep trap nets were not fished whitefish were taken in approximately two per cent of the trap nets, an estimate that the percentage of deep trap nets in the total trap net lifts is two less than the listed effective percentage for whitefish probably varies insignificantly from the truth. In the computation of average lifts for the two types of gear all whitefish and trout are considered to come from deep trap nets, and the catches of species other than the aforementioned two are credited to shallow traps. The examination of individual fishing reports justifies the procedure.

The selection of units of effort and intensity hinged upon the question of convenience in treating the data of the original report sheets. As defined they do not represent equivalent amounts of labor on the part of the fishermen. An understanding of the relative effectiveness of the various types of gear as represented by returns to the fisherman for his labor can be obtained better from a comparison of their catches for a typical day's fishing. A lift of 30,000 feet of gill nets is considered a reasonable day's work. It is estimated that lifts of seven deep traps, eleven shallow traps, ten pound nets, or 2,400 hooks correspond approximately to the above mentioned gill net lift. On the basis of the above assumptions the daily yields for the various types of gear have been computed. (Table 15). The table shows that from the standpoint of daily yield in pounds the 4½" mesh gill net is the least effective gear and the pound net the most effective. The deep trap gave excellent yields during the year of its introduction. The yield fell off slightly during the second year and suffered a tremendous decrease during the third. Of course the various types of gear vary as to the species composition of the catch and consequently as to the value per pound of the fish taken. It is, however, beyond the scope of this investigation to enter into a discussion of prices, marketing, or the general economic problems of the fisheries.

Table 16 shows the nature of the annual summary which is pre-

pared for each important species in each fishing district. In view of the preceding discussion no further explanations of the contents of the table should be necessary.

There will be offered a single example of the application of statistical data to a practical fisheries problem. The year 1928 saw the introduction into Lake Huron of the deep trap or "sub" for the capture of whitefish.[1] In 1930 the deep trap had become fairly common, and since that time there has been a regular increase in its use. The efficiency of this type of gear is so great that there have arisen grave fears that its continued use may result in a serious, even disastrous depletion of the whitefish stock. Table 17 shows the position of the deep trap in the whitefish fishery of northern Lake Huron over the period 1929-1932. These data show that the changes in total whitefish production in District I were in large measure, although by no means entirely, dependent upon the changes in the production of the deep trap nets. The catch per unit effort was greatest in the year deep trap nets first became common, decreased slightly the following year, and fell off markedly during the third year of their use. Simultaneous with the great decrease in the catch per unit effort there occurred a falling off in the number of deep trap nets fished.

No definite conclusions can be made as to the effect of deep trap nets on the fishery for whitefish until the statistics of the catch have been analyzed for the entire lake. The 1933 statistics should offer further important data. In general the spread of the deep trap in Lake Huron has been from north to south. There is some reason for belief that the introduction of this gear into a new locality is followed by two years of good fishing, while the third season is at least a partial failure. The catch statistics should show whether this gear does actually accomplish such a rapid and severe depletion of local whitefish populations.

SUMMARY

There has been presented a description of the methods which are being developed for the treatment of the statistics of the commercial fisheries of the Great Lakes.

The tabulation of the yield in geographic districts by gear and by species for each year and each month offers no innovations on the methods ordinarily employed for the study of commercial fisheries statistics.

The existence in the Great Lakes of distinct and separate fisheries which employ identical types of gear, and the seasonal and geographic variations in the average fishing time of the various types of gear have made nec-

[1]For descriptions of the deep trap net and discussion of the problems which have resulted from its use consult: Jobes, Frank W.—Deep trap nets on Lakes Huron and Michigan. The Fisherman, Vol. I, No. 3, February, 1932, Grand Haven, Michigan. Westerman, Fred A.—The deep water trap net and its relation to the Great Lakes Fisheries. Trans. Am. Fish. Soc., 1932, pp. 64-71.

essary certain improvements on the common method of describing fishing effort as the total amount of gear lifted, total number of seine hauls, total trawling hours, etc. In the study of fishing effort the following terms are defined:

I. Fishing effort

a. The fishing effort in a day's lift is the amount of gear lifted (in terms of units which have been defined on pages 295 and 296.

b. The total fishing effort with respect to a particular type of gear and over a specified period of time is the sum of the separate lifts.

c. The effective fishing effort with respect to a particular species, a particular type of gear, and over a specified period of time is that part of the total fishing effort which has resulted in the capture of any quantity of that species.

II. Fishing intensity

a. The fishing intensity in a day's lift is the product, fishing effort x fishing time (nights out). Special intensity units have been defined on pages 295 and 296.

b. The total fishing intensity with respect to a particular type of gear and over a specified period of time is the sum of the products, effort x fishing time, as computed separately for each day's lift.

c. The effective fishing intensity with respect to a particular species, a particular type of gear, and over a specified period of time is that part of the total fishing intensity which has resulted in the capture of any quantity of that species.

There have been offered examples to show the applications of the methods to the study of seasonal and annual fluctuations in yield and abundance and to the study of fishing gears, their seasonal and annual changes in yield and catch composition, and the relative importance of each type of gear in the general fishery.

TABLE 1

Lake Huron, District 1. Catch in Pounds of Each of the More Important Species in the Commercial Fishery, 1929-1932

Year	Trout	Whitefish	Chubs	Suckers	Menominee	Yellow Pike	Perch	Herring	Miscellaneous	Total
1929	374,328	385,280	241,005	234,987	48,813	14,914	19,525	28,135	61,723	1,408,710
1930	475,444	692,735	352,769	178,428	41,543	25,054	19,389	22,611	112,312	1,920,285
1931	542,161	941,768	420,335	372,119	33,154	36,506	21,753	11,902	135,582	2,515,280
1932	511,101	593,999	443,302	568,872	18,167	40,832	24,443	8,173	74,143	2,283,032
Total	1,903,034	2,613,782	1,457,411	1,354,406	141,677	117,306	85,110	70,821	383,760	8,127,307
Per ct.	23.42	32.16	17.93	16.66	1.74	1.44	1.05	0.87	4.72	

TABLE 2

Lake Huron, District 1. Catch in pounds (all species) for each type of commercial fishing gear, 1929-1932

Year	2¾" Gill Net	4½" Gill Net	Trap	Pound	Hook	Fyke	Hoop	Seine	Gear Unknown	Total
1932	470,473	364,316	865,907	415,118	123,122				44,096	2,283,032
1931	465,992	500,187	881,251	445,413	112,929	1,485		26,550	81,473	2,515,280
1930	414,598	444,209	520,146	443,638	52,764		3,219		41,711	1,920,285
1929	300,359	512,787	269,404	265,265	47,155				13,740	1,408,710
Total	1,651,422	1,821,499	2,536,708	1,569,434	335,970	1,485	3,219	26,550	181,020	8,127,307
Per ct.	20.32	22.41	31.21	19.31	4.13	0.02	0.04	0.33	2.23	

TABLE 3

Lake Huron, District 1. Catch in pounds in 4½" mesh gill nets, 1929-1932 Listed according to species

Year	Trout	White-fish	Chub	Sucker	Meno-minee	Yellow pike	Perch	Herring	Miscel-laneous	Total
1929	260,934	213,371	145	26,831	9,115	325	5		2,061	512,787
1930	275,139	146,925	5	8,401	1,888	1,397	191	38	10,918	444,209
1931	286,594	207,816		1,617	533	157	618		2,852	500,187
1932	255,660	104,824	178	1,143	1,412	250			849	364,316
Total	1,078,327	672,936	328	37,992	12,948	2,129	814	38	15,987	1,821,499
Per ct.	59.20	36.94	0.02	2.09	0.71	0.12	0.04	0.00	0.88	

TABLE 4

Lake Huron, District 1, 1931. Monthly catch, in pounds, of all types of gear combined for each of the more important species in the commercial fishery

Month	Trout	Whitefish	Chub	Sucker	Menominee	Yellow Pike	Perch	Herring	Misc.	Total
January	61,868	390	5,235	799	174		93	689	409	69,657
Feb'ary	18,228	220	6,568	5,520	1,267		260	855	916	33,834
March	11,921	297	9,273	4,329	1,520		62	259	2,520	30,181
April	50,627	54,719	22,133	13,411	1,347			2,192	10,675	155,104
May	55,046	146,823	41,113	42,245	4,046	75		849	13,987	304,184
June	53,252	293,630	36,038	102,823	2,825	2,408	1,206	1,009	19,735	512,926
July	43,152	138,733	66,327	56,335	6,135	2,689	663	1,218	3,768	319,020
August	53,006	126,635	55,316	50,395	4,684	15,208	2,943	272	19,428	327,887
Septe'r	52,006	86,640	66,822	35,226	579	12,492	6,795	553	34,127	295,240
October	91.862	33,375	54,693	13,116	2,822	3,175	2,455	2,056	24,428	227,982
Novem'r	31,490	41,801	36,886	12,337	5,813	452	6,008	906	5,231	140,924
Decem'r	19,703	18,505	19,931	35,583	1,942	7	1,268	1,044	358	98,341
Total	542,161	941.768	420,335	372,119	33,154	36,506	21,753	11,902	135,582	2,515,280
Percent.	21.55	37.44	16.71	14.79	1.32	1.45	0.86	0.47	5.39	

TABLE 5

Lake Huron, District 1, 1931. Monthly catch (in pounds) of pound nets, listed according to species

Month	Trout	Whitefish	Chub	Sucker	Menominee	Yellow Pike	Perch	Herring	Misc.	Total
January										
February	45							23		68
March	80	55								135
April										
May	7,937	19,150			18	65		15	165	27,350
June	20,712	142,159		671	1,161	104			2,800	167,607
July	12,164	63,585		663	11	205		455	6	77,089
August	4,464	30,665		3,872	14	985	412	177	2,304	42,893
Septem'r	6,426	34,272	30	2,081	16	2,989	22	362	7,967	54,165
October	12,870	23,223		286	86	787	40	1,914	1,479	40,685
Novem'r	4,522	29,688		3	149	59				34,421
December	651	349								1,000
Total	69,871	343,146	30	7,576	1,455	5,194	474	2,946	14,721	445,413
Percent.	15.69	77.04	0.01	1.70	0.33	1.17	0.11	0.66	3.31	

TABLE 6

Lake Huron, District 1. Annual catch of whitefish (in pounds) in each type of effective fishing gear, 1929-1932

Year	2¾-Inch Gill Net	4½-Inch Gill Net	Trap	Pound	Gear Unknown	Total
1929 ———		213,371	1,332	170,466	111	385,280
1930 ———	957	146,925	203,903	336,736	4,214	692,735
1931 ———		207,816	367,001	343,146	23,805	941,768
1932 ———		104,824	160,962	313,500	14,713	593,999
Total ———	957	672,936	733,198	1,163,848	42,843	2,613,782
Percentage	0.04	25.75	28.05	44.53	1.64	

TABLE 7

Lake Huron, District 1, 1931. Monthly catch of whitefish (in pounds) for each effective type of fishing gear

1931	4½-Inch Gill Net	Trap	Pound	No Gear Listed	Total	Percentage
January	390				390	0.03
February	220				220	0.02
March	125		55	117	297	0.03
April	41,726	12,993			54,719	5.81
May	57,561	70,112	19,150		146,823	15.59
June	31,201	104,943	142,159	15,327	293,630	31.18
July	18,932	51,202	63,585	5,014	138,733	14.73
August	24,560	71,203	30,665	207	126,635	13.45
September	7,936	42,455	34,272	1,977	86,640	9.20
October	225	9,927	23,223		33,375	3.54
November	6,847	4,103	29,688	1,163	41,801	4.44
December	18,093	63	349		18,505	1.96
Total	207,816	367,001	343,146	23,805	941,768	
Percentage	22.07	38.97	36.44	2.53		

TABLE 8

Lake Huron, District 1, 1931. Number of pound nets lifted during each month and the number of lifts which contained catches of each of the important species

1931	Trout	Whitefish	Chub	Herring	Sucker	Pike	Perch	Total Lift In Month
January								
February	2			10				10
March	27	27						27
April								
May	288	300		3		17		310
June	798	858			10	58		858
July	633	685		12	21	55		696
August	351	477		12	54	106	17	490
September	461	689	6	82	179	349	4	691
October	436	533		81	5	211	2	658
November	168	220			2	20		230
December	20	16						20
Total	3,184	3,805	6	200	271	816	23	3,990
Percentage Effective	79.80	95.36	0.15	5.00	6.79	20.45	0.58	

TABLE 9

Lake Huron, District 1. Total fishing effort (gear lifted) for each type of gear for each year, 1929-1932[1]

Year	2¾" Gill Net	4½" Gill Net	Trap	Pound	Fyke	Hoop	Hook	Seine
1929	14,590	24,799	5,162	2,567			146	
1930	13,981	18,747	5,051	2,939		23	258	
1931	14,856	26,410	7,663	3,990	51		427	17
1932	16,378	20,631	9,764	4,060			488	

[1]Units of effort are: gill nets, 1,000 ft. lifts; trap, pound, fyke, hoop—1 net lift; hooks, 1,000 hook lifts; seine, 100 rod hauls.

TABLE 10

Lake Huron, District 1. Total fishing intensity[1] for each type of gear for each year, 1929-1932. Below, the average fishing time (in days) for each type of gear

Year	2¾" Gill Net	4½" Gill Net	Trap	Pound	Fyke	Hoop	Hook	Seine
1929	92,889	87,591	34,463	7,676			541	
1930	82,248	69,813	26,825	7,932		161	956	
1931	89,026	86,829	38,550	10,435	227		1,701	17
1932	98,120	73,449	44,926	10,910			1,991	
Average Fishing Time	6.1	3.5	5.2	2.7	4.5	7.0	3.9	

[1]Units of fishing intensity: gill nets, 1,000 ft. nights; trap, pound, fyke, hoop—1 net night; hooks, 1,000 hook nights; seine, 100 rod hauls.

TABLE 11

Lake Huron, District 1, 1931. Trout fishery: Yield per unit fishing effort and per unit fishing intensity expressed for each type of gear with respect to both effective and total effort and intensity. Below, total catch in pounds in each type of gear

	2¾" Gill Net	4½" Gill Net	Trap	Pound	Hook
Catch per Lift—Effective Gear	0.60	11.09	22.41	21.94	263.80
Catch per Lift—Total Gear	0.48	10.85	7.86	17.51	263.80
Catch per Night—Effective Gear	0.10	3.36	5.77	8.62	66.22
Catch per Night—Total Gear	0.08	3.30	1.56	6.70	66.22
Total Catch in Pounds	7,066	286,594	60,236	69,871	112,644

TABLE 12

Lake Huron, District 1, 1932, Pound net fishery: Catch per unit effort and per unit intensity for each of the important species. Values are given with respect to both effort and total effort and intensity. Below, catch in pounds of each of the important species

	Trout	Whitefish	Herring	Sucker	Yellow Pike	Miscellaneous	Total
Catch per Lift—Effective Gear	25.10	79.27	8.07	35.20	7.17		
Catch per Lift—Total Gear	20.02	77.22	0.77	2.22	1.28	0.88	102.39
Catch per Night—Effective Gear	9.15	29.62	3.17	11.32	2.30		
Catch per Night—Total Gear	7.39	28.74	0.29	0.83	0.48	0.32	38.05
Catch in Pounds	80,651	313,500	3,143	9,010	5,206	3,608	415,118

TABLE 13

Lake Huron, District 1. Catch in pounds per unit effort and per unit intensity for each type of gear used in the commercial fishery, 1929-1932. These catches are based on all gear fished and on the combined catches of all species taken in a particular type of gear

	2¾" Gill Net	4½" Gill Net	Trap	Pound	Fyke	Hoop	Hook	Seine
1929 Catch per Unit Effort	20.59	20.68	52.19	103.34			322.98	
1929 Catch per Unit Intensity	3.23	5.85	7.82	34.56			87.16	
1930 Catch per Unit Effort	29.65	23.69	102.98	150.95		139.96	204.51	
1930 Catch per Unit Intensity	5.04	6.36	19.39	55.93		19.99	55.19	
1931 Catch per Unit Effort	31.37	18.94	115.01	111.63	28.11		264.47	1,580.35
1931 Catch per Unit Intensity	5.23	5.76	22.86	42.68	6.54		66.39	
1932 Catch per Unit Effort	28.73	17.66	88.71	102.39			252.30	
1932 Catch per Unit Intensity	4.80	4.96	19.27	38.05			61.84	

TABLE 14

Lake Huron, District 1. Trap net fishery: Changes in the percentage effort exerted for the capture of whitefish, suckers, and trout, 1929-1932

	1929	1930	1931	1932
Percentage Trap Nets Taking Whitefish	2.38	29.80	36.97	20.17
Percentage Trap Nets Taking Suckers	96.24	73.25	64.92	81.06
Percentage Trap Nets Taking Trout	4.22	23.84	35.08	17.39

TABLE 15

Lake Huron, District 1. Comparison of the yield in pounds from an average day's fishing with each of six types of fishing gear. The data are based on the assumption that the following lifts represent equivalent amounts of labor on the part of the fishermen; gill nets, 30,000 feet; deep trap nets, 7; shallow trap nets, 11; pound nets, 10; hooks, 2,400

Year	2¾" Gill Net	4½" Gill Net	Deep Trap Net	Shallow Trap Net	Pound Net	Hooks
1929	618	621		574	1,033	775
1930	891	711	1,128	826	1,509	491
1931	942	567	1,037	1,004	1,116	635
1932	861	531	681	937	1,024	606

TABLE 16

Lake Huron, District 1. Summary of Trout Fishery, 1931

Type of Gear	2¾" Gill Net	4½" Gill Net	Trap	Pound	Hook	No Gear Recorded
Catch in gear	7,066	286,594	60,236	69,871	112,644	5,750
Percentage of total trout in gear	1.30	52.86	11.11	12.89	20.78	1.06
Percentage of gear's catch	1.52	57.30	6.84	15.69	99.75	
Percentage of gear with trout	78.90	97.85	35.08	79.80	100.00	
Catch per night (effective)	0.10	3.36	5.77	8.62	66.22	
Catch per night (total)	0.08	3.30	1.56	6.70	66.22	
Catch per lift (effective)	0.60	11.09	22.41	21.94	263.80	
Catch per lift (total)	0.48	10.85	7.86	17.51	263.80	

TABLE 17

Lake Huron, District 1. Data to show the position of the deep trap net in the fishery, 1929-1932

	1929	1930	1931	1932
Total yield of whitefish	385,280	692,735	941,768	593,999
Whitefish taken in trap nets	1,332	203,903	367,001	160,962
Per cent of total whitefish taken in trap nets	0.95	29.43	38.97	27.10
Change in yield of whitefish		+307,455	+249,033	—347,769
Change in yield of whitefish from trap nets		+202,591	+163,098	—206,039
Change in trap net yield as percentage of total change in yield		65.89	65.49	59.25
Catch of whitefish per net lift	10.83	135.48	129.55	81.75
Catch of whitefish per net night	0.95	40.83	32.72	21.50
Number of net lifts with whitefish	123[1]	1,505	2,833	1,969

[1]These lifts probably represent incidental captures of whitefish in shallow trap nets.

A NEW METHOD OF MARKING FISH BY MEANS OF INTERNAL TAGS

ROBERT A. NESBIT
*U. S. Bureau of Fisheries**

In the course of investigation of the causes of fluctuations in yield of the squeteague *(Cynoscion regalis,* Bloch & Schneider) in the Middle Atlantic States, a need for tagging experiments became apparent. The usual methods were not well adapted to the needs of the investigation, for the squeteague is so soft-fleshed and so weak-boned that tags of the usual designs are quickly lost. Moreover, the most pressing problems were concerned with the movements of squeteague of the "0" and "I" age groups, comprising fish between 6 and 11 inches in length. These small fish were found to lose tags even more quickly than adults.

Of a number of methods tested on fish confined in live cars, only one proved well adapted to the severe requirements of the problem. This method, first tested in August 1930, consists of insertion of printed and numbered strips of colored celluloid into the coelom, where they are found when the recaptured fish are cleaned. It was found in the live-car experiments that the wound healed quickly, usually within ten days, and that no inflamation or irritation of the viscera resulted. No mortality attributable to the operation occurred, for in all of the five experiments with three species, no deaths occurred within three months of the date of tagging, and fewer tagged fish than unmarked controls died subsequently. Two of the experiments were continued longer than a year, during which time no tags were lost and no internal irritation developed. In these experiments scup as small as 4", brook trout as small as 5", and squeteague as small as 8" were marked successfully.

Encouraged by the results of the aquarium experiments, the method was tested further by release of marked squeteague, scup and cod at sea. Returns from these experiments have ranged between 1.5 and 10 percent and may be expected eventually to be somewhat greater, as recaptures are still being reported. In the squeteague experiments, fish as small as 6" have been tagged successfully as evidenced by their subsequent recapture.

By means of this method it has been possible to demonstrate that "0" class squeteague at Montauk, New York, averaging 8" in length, migrate to southern waters during the winter. The following summer they appeared in the coastal waters of Virginia and New Jersey.

Some difficulty has been experienced in securing adequate information concerning the locality and date of recapture of scup and squeteague, for these species are more frequently cleaned by deal-

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ers or the ultimate consumer than by fishermen. So much time is lost in correspondence with the finders that it is frequently difficult to trace the shipment of fish to the locality of recapture. It is expected that tags recently developed will substantially diminsh this difficulty. These tags bear, in addition to the identifying number, the following printed inscription: "Reward—Mail at once to Bureau of Fisheries, Washington, D. C. State when and where caught or when and from whom purchased. Measure fish by tracing its outline carefully on paper. Send about twenty scales from each side of fish." These tags are manufactured to the Bureau's specifications by makers of celluloid advertising specialties. For squeteague between 6 and 8" in length, tags 1¼" x 5/16" are used, and for fish longer than 8", tags are 1¾" x 5/16".

Although this method was developed primarily for tagging marine species, it appears to be well adapted to the requirements of experiments with fresh water game fishes. In particular, its adaptibility to small fish is advantageous. My own experience with tagging of fresh water fishes is limited to a single successful experiment with brook trout in the spring of 1931. The method was kindly tested further by Dr. John R. Greeley of the Institute for Fisheries Research, University of Michigan, Ann Arbor, Michigan, who informs me that all of his trout died from furunculosis, the infection being, no doubt, introduced with the tags. It appears necessary, therefore, to observe greater precautions to prevent infection than with marine fishes. In the spring of 1933, on the recommendation of the author, this method was used successfully by the Connecticut State Board of Fisheries and Game in a large-scale experiment with brook trout and brown trout.

RESULTS OF TROUT TAGGING TO DETERMINE MIGRATIONS AND RESULTS FROM PLANTS MADE

Eben W. Cobb

Supt. Fish Restoration, Connecticut Board of Fisheries and Game

After many years of experimentation in feeding and holding trout it was our opinion that the results were satisfactory, at least in comparison with others. We have been planting in the neighborhood of 240,000 adult trout per year with a weight of about twenty-three tons, showing good color and generally healthy appearance. We have avoided as much as possible the "truck following" massed planting, etc. We have devised a shipping tank which will hold trout for a good length of time so as to give a better opportunity for wide scattering. This season we have experimented with planting trout from floating live cars and have compared this with plants made by carrying them in buckets from the trucks.

After these efforts were made to furnish as good fishing to the angler as possible, we were desirous of securing information as to the real results which we were producing. It was decided, therefore, to tag some trout and liberate them under circumstances such as would give us the information desired. The method decided upon was internal tagging which was originated in the Bureau of Fisheries and was developed, mostly with marine fishes, under the supervision of Prof. Robert A. Nesbit, Asst. Aquatic Biologist, located at Harvard University. After securing samples of tags such as had been used we considered changes necessary to make them suit our purposes. The principal improvement was that lettering was printed instead of being written by hand and the construction was so changed as to provide a thin transparent covering for the tag. This covering helped materially to prevent the tag from warping after being placed in the trout. We are glad to acknowledge the co-operation of Bastian Bros. of New York in working out these details.

Experimental work was carried on with the placing of the tags and examinations were made afterward to determine the exact location of the tags in the trout. It was found in tests which lasted a few days that some of the tags were discharged, but such loss was comparatively small. The loss seemed to vary with location or direction of slit, or other variation in technique. The method finally adopted was to make a cut perpendicular to the lateral line and well back in the abdominal cavity, the cut being of exact size to receive the tag. Two men were employed; one to hold the fish, the other to make the cut and insert the tag. By placing the tags which were discharged in other trout, the number to be shipped was complete, though a small loss in this manner undoubtedly took place after planting.

We purchased tags and placed 15,875 in trout which were planted in public waters and eventually had a return of 5,403. This large return was accomplished by carefully planned publicity and by offering prizes for the lucky numbers which would be taken from the returns. It is presumed that the number of tags sent in was a considerable proportion of the number taken. The returns show 33 per cent, but we believe that a reasonable estimate of the number would be not over 50 per cent allowing for lost tags, etc.

It would seem, therefore, that the greatest opportunity for progress lies not so much in the distribution of *more* trout but in the improvement of natural conditions so that the loss of trout after planting may be reduced.

Our patrolmen on leased streams have always checked the trout caught, but this season the patrol was on full time for the first thirty days only, part-time for the balance of the season. This included week-ends and records show that many of the trout were caught on Saturdays and Sundays. This patrol covering week-ends matched fairly well with the tag returns.

In tests made in the past we have secured very poor results from stocking in the summer or fall to carry over till the following season. By checking on the catch of the carry-over from these tagged trout next season we had hoped to get an idea as to the results of the previous season's planting. The effect of the tags on the trout, especially during the spawning season, is uncertain and it will be impossible to account for any loss in these numbers which may take place. It is very likely that the usefulness of these experiments is confined principally to determining movements and catches shortly after planting.

However, for a check we tagged two hundred trout and placed them in a small pond in which we had previously held four hundred trout without a loss of any amount. A personal check on many of the losses of these tagged trout has shown that many of the tags had become imbedded in the ovaries or the milt causing inflammation. In some cases the tag had moved to a position diagonally across the trout and in others it had worked forward so as to interfere with the vital organs or the swimming bladder. Of the two hundred trout used in this experiment the loss has been 155.

It was requested that anyone taking a trout with a tag in it should forward the tag to the Department, with information as to the date when caught, the stream and the location on the stream, the method of the catch and any other matter which might be of interest.

Some of our leased streams are for brown, brook and rainbow trout and some are for one species only. One stream is planted with all three for its entire length. In speaking of a "leased stream" we mean that portion of a stream on which leases are held and

trout can of course pass from the leased portions onto other property.

Locations were selected toward the upper and lower end of each stream to be tested and in March when the first plants were made we placed a consignment in each of the two places, with a record kept of the numbers on the tags for each of the two locations.

In statements as to the up and down stream movements of the trout this gave them a considerable leeway, as they were not classed as having moved unless they were taken outside of the portion of the stream in which they were planted. In some instances the portion was several miles long.

In the smaller streams and in streams open to public fishing, but not leased, we planted consignments along the entire length of open waters and did not attempt to compile detailed information as to movements, except into tributaries. Later during the open fishing season we placed certain consignments in short stretches of streams to determine the results with reference to immediate capture.

The total number of streams stocked with tagged trout and on which records were kept was thirty-five.

Taking as an example ten streams in which were planted 4,429 tagged brook trout and 4,250 tagged brown trout, we find that of the entire lot 2,713 or 31 per cent were taken. The percentage of the total plant of brown trout caught was about two-thirds as great as the percentage of brook trout. Of the entire catch 75.5 per cent were caught in the section where planted, 6.5 per cent had moved upstream, 14.5 per cent had moved downstream and 3.5 per cent had moved into tributaries.

A comparison of the movements of brook and brown trout in four streams in which both species had been planted shows the following results. Taken in the section in which planted, brook trout 79.7 per cent and brown trout 66.5 per cent. Upstream, brook trout 6.9 per cent and brown trout 6.8 per cent. Downstream, brook trout 9.1 per cent and brown trout 26.6 per cent. In tributaries, brook trout 4.3 per cent and brown trout 0.1 per cent. This tends to prove the correctness of our idea that our brown trout should be planted where a run downstream will place them in a good body of water rather than in a polluted stream. It also tends to show that the brown trout has no great tendency to go to the smaller and colder waters above, which are in many instances inhabited by brook trout and utilized by them as a breeding ground.

For the purpose of a fair comparison of movement and catch, let us consider the Farmington River where we have about twelve miles of leased waters. In this stream, brook, brown and rainbow trout were planted throughout the entire length and consequently mixed together since there was no barrier sufficient to obstruct the run of trout up or down stream.

In this stream there were planted 600 tagged brook trout and 750 tagged brown trout, or a total of 1,350. Of these 31 per cent were reported as caught. Of the entire number caught and reported as to location, 7 per cent had moved upstream, 14 per cent had moved downstream, 2 per cent into tributaries and 77 per cent were caught in the section in which they were planted.

In this stream where conditions for all species are the same, the catch of brown trout shows a much smaller percentage than the catch of brook trout. The percentage of brown trout runs about two-thirds that of brook trout, which checks closely with the results of the combined ten streams selected for comparison. This is doubtless due to the fact that brook trout are more easily caught after planting than are brown trout.

As an example of the catch following the planting of trout in open season, we will consider the results following the introduction of tagged trout into this river. On April 24th there were planted 250 tagged brown trout in addition to those already there. The first return, a brown trout tag, after this plant, was on April 27th, when one tag not from this lot, was returned. On the 28th six were returned, four of which were from this lot. On the 30th, six were returned, three being from this lot. The greatest number of tags taken on one day was ten on May 30th, thirty-six days after a plant had been made.

On May 25th, 100 tagged brook trout were planted in this stream, all being placed in a very short distance. On that date no brook trout tags were returned from this stream, but on the following day fifteen were returned, all from this plant, making the largest return of any day in the season. The next day six tags from this lot were returned.

In the Pomperaug River, in which brook trout were planted in the upper portion and brown trout in the lower portion, with a dam between, the results were good in each case. About 38% of the brook trout were taken with a slightly less percentage of the brown trout, with a total of 36%. In this case 64% were taken in the section where planted, 8% moved upstream, 22% moved downstream and 6% were taken in tributaries. This stream has a good many spring fed tributaries which are attractive to trout, but a number of them are closed to all fishing, which would have some effect on the report on movements. The dam also has its effect on the upward movements of the brown trout.

Salmon River is considered a typical brown trout stream, but during the past season, for purposes of our experiment, an equal number of brook trout were also planted in it. The result of the brook trout planting was very poor, as shown in the reports of the patrolmen and the return of tags. The return on tags from the brook trout was only about 11%, while from brown trout it was about 39%. Of the total returns from this stream where the location was

given, 76% were taken in the section where planted, 12% moved upstream and 12% moved downstream.

The Natchaug River is one of our best brook trout streams and no other species are planted there. This stream received 1,200 tagged brook trout and 404 or slightly over one-third were reported as caught. Of this number 75% were taken in the section where planted, 2% moved upstream, 8% moved downstream and 15% moved into tributaries.

A plant of 500 tagged brook trout was made here on March 6th, and another of 500 on April 1st, making a total of 1,000 before the opening of the season on April 15th. On the first day of the open season 42 of these were reported as caught. On the same day 117 fishermen were checked on this stream by the patrolmen. On the following day 22 were caught, with a check of 50 fishermen. The largest catch was made on April 23rd, with a check of 45 trout and 79 fishermen. This was 23 days after the last plant was made and the number was three more than on the first day of the season, when 117 fishermen were checked.

A further plant of 200 was made on June 1st. On that day no tags, either from these or others previously planted, were taken. On the following day one was taken, on the next 8 and on the third day after planting 9 were taken. The largest catches almost always prove to be on Sunday, when people have all day to fish.

These four streams show the results from the four varieties of streams which we have in the State.

In addition to the information secured as to movements and catches, one other object has been achieved. It has shown the angler that good trout can be produced in the hatcheries.

The sportsmen in general consider a well formed and good colored trout as a "native," while a poor colored or poorly developed trout is to them a "liver fed" or "hatchery trout." This year many trout have been caught which were considered "natives" but which proved to have a tag of this year's plant in them. In the ten streams considered two tags were taken from the bottom of the stream. Five were taken from the dead bodies of trout found dead in the streams. One was taken from the digestive organs of an eel. One was taken from the interior of a partly digested brook trout found in the stomach of a larger brown trout.

Early in the season the newspapers gave much publicity to reports of a brown trout having moved fifty miles downstream and to one having gone down one tributary to a large stream and up another tributary. It does not do to accept this publicity without question. We must depend upon proven facts as shown by experiment and investigation.

Discussion

Mr. Adams: I would like to ask Mr. Cobb to what extent he made observation on any rainbows released as showing a tendency for them to move out of the country.

MR. COBB: No rainbows were included in this tagging—they were all brook and brown trout.

MR. ADAMS: But you mentioned having put all three species in the Farmington River.

MR. COBB: There were rainbows in there, but that is a stream in which we put all varieties of fish.

MR. ADAMS: In your observation of rainbows after planting, to what extent are they likely to stay put or to move out?

MR. COBB: I find them very likely to go down stream.

MR. ADAMS: How far down stream?

MR. COBB: Under the conditions such as we have, if we plant them in a stream that runs into one of the streams with manufacturing on it they apparently go into that stream and are lost. If we put them in a clear water stream with a deep lake outlet we find they are finally caught in the lake itself.

MR. ADAMS: Do you figure they will run to sea if they get the chance, and stay there in the brackish waters?

MR. COBB: If they do not find a suitable place before they get there, I think they will to a large extent.

MR. ADAMS: Have you found any strain of rainbows that is more likely to stay put than another? For example, there are two or three breeders in the eastern states who have brood stocks that are probably from twenty to twenty-five years old, which means that they have kept up a particular strain. Then to some extent in the eastern states we have imported and hatched the migratory steelhead. It seems that we have two strains of rainbows, one that is less likely to move out of the country than the other. I would be much interested to have some comment on that—whether we are ever likely to develop a strain of rainbows that is more likely to stay put than some of the ones we deal with now.

MR. COBB: I have not had enough experience with these later strains to be able to say. But at present we are securing from those men of whom you spoke, rainbow eggs which are fall spawned and give us trout of the right age for reproduction at the right season of the year to suit our conditions. We are selecting streams which run into clear water deep lakes for the planting of these rainbows, in the hope that with the downward run we would develop a large rainbow in these lakes or ponds, of which we have selected several in our state.

MR. ADAMS: As bearing out the wisdom of that plan, originally the tributaries of some of the large Finger Lakes were stocked with rainbows that were regarded as suitable for these tributaries, but not in relation to the lakes themselves. In recent years large rainbow trout are being taken out of several of the Finger Lakes, bearing out just the very plan you have in mind.

MR. COBB: That seems to be the nature of the fish; if they strike suitable water of the proper depth before they get down the stream, they will largely stay there, I believe. That is why we are working in that way.

MR. T. SURBER: A few years ago I called attention to the so-called Missouri

rainbows we obtained from Missouri. We have had varying luck in Minnesota with these fish. In one river, the Cannon, which has several dams along its course, we find they remained between these dams at least up to the age of four years, and made remarkable growth; they grew at the rate of about a pound a year in these waters. In certain other streams in which we placed them they apparently found the conditions unsuitable and have gone down to the lakes. For instance, in some of our northeasterly streams tributary to Lake Superior, they have gone into Lake Superior, but they are not lost, because they are caught in large numbers around the mouths of the rivers. I am confident that under normal conditions, where the trout spawn, as these have done, in the fall, they will remain in these streams permanently, as shown on the Cannon, where conditions are suitable. They will not stay in the small streams; they go down into the large pools for the winter.

MR. ADAMS: My observation is that the fall spawners are more likely to stay put, and it seems desirable, particularly for our eastern waters, by selective breeding and care in manipulating our rainbow brood stocks to build up a strain of fall spawning fish as being possibly one of the solutions of this question.

MR. COBB: These we are securing are fall spawning, but we do not hold the brood stock; we get them from dealers.

MR. ADAMS: You are not building up any brood stock?

MR. COBB: No, we are not experimenting with brood stock, but we are getting them from people who are, and in that way we get a fish that is of an age that matches with our seasons. Some of these rainbows have grown as yearlings to weigh over half a pound in our spring water ponds.

DR. GREELEY: The factor of population intensity may make a great deal of difference as to whether or not rainbows will stay in the streams to maturity. Assuming that the rainbows we have in Michigan are all the same thing—I do not know whether they are or not—we find that a number of streams have a limited number of rainbows staying in them and maturing. For instance, the Pigeon River has a number of rainbow that get up to eighteen or nineteen inches every year, and they mature, but the population intensity is not very high—those fish are just scattered along in the larger pools and evidently find enough food to enable them to stay there. In the main spawning streams for the Lake Michigan run of rainbow there are large numbers of small rainbow trout, and under that condition we do not find very many of the rainbows staying there; they are practically all migratory. So there is a possibility that the number of fish in relation to their food supply is a very important factor in determining whether or not the rainbow trout will stay in the stream.

MR. ADAMS: I would like to get some information out of Charlie Hayford on this, because he has probably played more with rainbow in eastern waters than any of us.

MR. HAYFORD: In New Jersey, although we have been working the rainbow trout for years, we have worked him only as a filler; we can keep him in the lower end of the hatchery where the water is warmer than we can

successfully raise brook or brown. They are one of the scrappiest fish we have; they rise to the fly, put up a good battle; many of the sportsmen are very fond of him from a catching point of view. We have a little stream running through the hatchery which is teeming with insect life of all sorts, and these rainbows stay right in that little stream and grow up from little bits of fellows to a length of eight or ten inches, and they are very highly colored. We have other streams in the state that we do not seem to get anything like that out of. Our best results come from planting these rainbow trout ten or twelve inches long—we do not plant anything less than eight—in streams that have a lot of mill ponds in them. Many of our New Jersey streams have a mill every mile or two—that is, old grain mills—and these rainbow trout have given exceptionally fine results in that type of stream. But in the case of the small warm streams we have had practically no results, and we have discontinued planting them in the fall of the year; we put the fish in during the fishing season—March, April, May and June. The fish are firm and well colored, because they are wintered in the large lakes in the hatchery, of about an acre. Our best results in securing rainbow trout have come from the Plymouth Rock hatchery. Last year we started in on the selective breeding in the rainbows, and I do not see any reason why they should not be as good as the other fish. We find in many instances it is a question of food and satisfactory environment. I have a tagging system that is fairly accurate that may give us some useful information along these lines.

Mr. Adams: In some of our eastern states we have had some mighty tough conditions with respect to drought, particularly in the last two or three years. We have streams that are well stocked with all three of the trouts, the brook, the rainbow and the brown. When we strike a drought condition we find that the rainbow appears to be much more resourceful and clever than the brown trout. The rainbow will work out of some of these areas that become stagnant and warm up. We have had instances of considerable mortality in the brown trout that we have attributed to these drought conditions, but there has not been so great a mortality among the rainbows, because they seem to respond to temperature conditions more quickly than the browns and get out of unfavorable areas.

Dr. Greeley: With regard to the method of tagging by insertion into the body cavity of the trout and other fish, Mr. Nesbit's paper mentioned some findings we have made in Michigan in that connection. Mr. Nesbit very kindly sent us some tags to try out, and he summarized the findings of our main experiment on that last fall. We had very poor luck at that one hatchery, due to unforeseen circumstances; the fish which had been tagged with the body cavity tag proved susceptible to disease—there were losses from furunculosis among the untagged fish, but the tagged fish were wiped out. When I first got hold of some of these tags I made a few experiments in a limited way with regard to putting them in. I tried this in another hatchery on eight fish, and these lived very well—several of them are still alive, as far as I know. So we did find that these body cavity tags work all right, although the first time I tried that experiment it was on so few

fish that it does not mean very much. I believe it has been brought out by Mr. Cobb's work, as well as the little experience we had, that you can get good results with the body cavity tag and you can get bad results. It does offer a chance for infection to get started if anything is going to hit these fish.

Mr. Cobb: The catch on the returns from these tags, averaging around one-third from all planted in actual return of tags, is considered satisfactory. But the point on which I am not satisfied is the returns from fish later on. If next year we get these tagged trout, that is all right, but if we do not, we do not know whether it was the tags or the conditions in the stream or something else that does away with them. As to this smaller experiment I carried out in the small pond, some other item may have entered into that. The trout develops the spawn and milt in the second year. As I understand it, the experiments first carried on with these tags were on large fingerlings. I take it the most serious interference with the life of the trout so far as the use of the internal tag is concerned is that it is placed where it would very likely interfere with the development of the spawn or the milt, which of course is very delicate. The next most serious thing is that the end is very likely to touch the swimming bladder, which of course is very tender. A large number of those we lost in this pond were fish which had started to develop the ovaries or the milt. It was interference with that that caused a large proportion of the deaths, because there was inflammation where the tags touched them.

The President: The question brought up by Mr. Adams as to migratory and non-migratory strains of rainbow is certainly a very complicated problem. At the present time in California, which as you know is the native home of the rainbow, we are attempting to get hold of a native non-migratory strain. We know that in certain streams in that state there are fish which have been in the headwaters for untold generations because they could not go anywhere else, and they at least are non-migratory. We do not know what will happen when we get them in a different environment, but we have hopes that the non-migratory habit has become so strongly ingrained in those fish that even when removed to other environments, provided the environments are satisfactory, they will remain non-migratory. I am also informed on good authority that in some of the Oregon streams there are rainbows which remain, even in the smaller streams, throughout the year, and show no tendency to migrate down into the larger waters or to the sea, although they have every means of doing so. I also know of at least one instance in Vermont where the rainbow has become firmly established as a resident fish. One remarkable thing about that particular stream, which is a beautiful brook trout stream in every respect, is that although no rainbows have been planted in it for several years and it has been stocked heavily each year with brooks, the rainbows are gradually increasing in numbers without any artificial assistance and are spreading up and down that stream. So I think there is no question that there is a distinct possibility of getting a strain of rainbows which will stay put in the same sense that brook trout or brown trout will. I have no doubt also that the en-

vironment has a great deal to do with it. This particular stream in Vermont, by the way, is very rich in food, and that bears out what Dr. Greeley says, that the food may have a great deal to do with it. I was interested in the point Mr. Adams made, that the rainbow is much more resourceful than the other species of trout when it comes to a matter of low water conditions. I am not surprised at that; the rainbow has developed in an environment where there are extreme fluctuations in volume of water and temperature; if they were not resourceful and could not adapt themselves to these conditions, they would have disappeared long ago.

Mr. Adams: At the risk of getting off the subject just a little, may I say there is a field of research in which I believe the American Fisheries Society can be of tremendous help, and it is this: In practically every state where the three trouts can be planted we find definite opposition to the brown trout on the part of what I would call the brook trout purist. An old fish culturist made the point some years ago—and I think I have seen this proposition demonstrated—that if you take the brook and the brown and put them in a given stream, the two species will more or less automatically sort themselves out in that stream, based on the temperature of the water; the brooks naturally work toward the colder headwaters and the browns work downstream, which would indicate that, if there is a conflict between the two forms that might at times be undesirable, in our larger streams we do not need to be very much afraid of that, because water temperatures will largely take care of the problem. I imagine, therefore, that in our eastern states, both or all three species could be planted to advantage based to a large extent on temperature control rather than the idea of insurmountable barriers on the streams and things of that kind. I do not know to what extent this has been exploited at past meetings of the Society; I cannot recall that there has been much said about it. But if in the next year or two or three some of the research workers were to sharpen that proposition up somewhat, it would give us the material to allay the fears of a good many brook trout as against brown trout enthusiasts.

The President: I think that is a very good suggestion. We have run against that same opposition in our own work.

Mr. Locke: In connection with the instances you mention of types of rainbow or steelhead which are resident, you might be interested to know that there are several lakes on the headwaters of the Salmon River in Idaho where specimens I collected and submitted to Dr. Kendall were determined to be identical with the Columbia River steelhead, but there was absolutely no possibility of their being migratory in those waters. They had been established there in several different places within a relatively large watershed in the small streams and lakes. I have had it in mind to carry on the experiment of taking some of these eggs and planting them in some other waters to see whether that characteristic was so strongly established that you would not get the migratory instinct.

Mr. Rodd: We have what we believe to be a non-migratory strain of rainbow trout—or perhaps I should put it this way: we have migratory trout that are staying where they were put. They were planted in the upper waters

of the foothill streams of the Rocky Mountains of Alberta; they worked down, but they did not pass through the waters on the prairie flats. In New Brunswick one of the tributaries of the Petitcodiac was stocked with rainbows thirty years ago. The Petitcodiac is a very muddy stream, but the tributary to which I refer is quite a clear, nice stream, and these fish have stayed in the upper tributaries. The same experience is found in Kenya Colony, Africa, in some of the streams in Ceylon and also in Derbyshire, England—they have there a non-migratory rainbow trout developed from stocks produced on this side.

THE EFFECTS OF TAGS UPON FRESH WATER FISHES

Henry C. Markus
U. S. Bureau of Fisheries

The process of tagging fish has been an effective means in solving the life history and migrations of fish. This is especially true of the salmon. Izaak Walton (1653) recorded the following brief notes on the tagging of salmon: "And for the Salmon's sudden growth, it has been observed by tying a Ribon in the tail of some number of the young Salmons, which have been taken in Weires, as they swimm'd towards the salt water, and then by taking a part of them again with the same mark, at the same place, at their returne from the Sea, which is usually about six months after." Since the time of Izaak Walton much time has been spent tagging fish and many different types of tags have been used in marking them. W. L. Calderwood (1901) notes various types of tags used by the early Scottish investigators in the marking of salt water fishes. These marks consisted of brass wire, cutting of fins and finally a very elaborate tag was developed, which consisted of a metal plate bearing a number soldered onto a wire. A Guide to Fish Marks used by members of the International Council for the Exploration of the Sea and by some non-participant countries illustrates the various types of tags used in marking fish of today.

Within recent years a great number of fresh water fishes are being tagged in this country by State Surveys and the Federal Government. In the summer of 1929 the author was employed by the Illinois State Natural History Survey to tag fish in the Sangamon River in Illinois. Since that time the author has been interested in keeping in contact with the results obtained from tagging of fresh water fishes. To date the results in literature are very fragmentary. It seems from the number of fish tagged only a small number are taken again with tags. This may be due to a series of causes which are: first, that the fish when caught bearing the tag by the fisherman is not reported; second, the fish may lose the tag; third, the fish carrying the tag may never be caught; fourth, the fish may die from the effect of the tag, or fifth, the fish may die a natural death. It is through these questionable causes that the author undertook this experiment of determining the effect of tagging upon fish at the U. S. Bureau of Fisheries Laboratory at Fairport, Iowa.

Procedure. Through the use of seines, trot lines and fyke nets 243 fish were caught from the Mississippi river and Sun Fish lake the last of August and the first of September, near Fairport, Iowa. These three types of tackle were used since they are the ones usually employed by agencies taking fish from these bodies of water for tagging purposes. Sun Fish lake is a small body of water located in the flood plain area of the Mississippi River. The river over-

flows the lake in high water stages. The 243 fish tagged consisted of twelve of the common species of food and game fishes found in the Mississippi River. These are listed in table I.

The fish when caught were put into tanks filled with water. They were then tagged and immediately released in the station reservoir. The area of the water surface of the reservoir was 1.5 acres and the depth was from 0 to 7 feet. Number 2 and 3 metal strap tags were used as described and illustrated in A Guide to Fish Marks (1932). Number 3 tags were used on the smaller species of fish and number 2 tags on the larger species. Number 2 tags were used on small fish if the species was a large type of fish. In a few cases this procedure was altered for merely experimental purposes. The greater number of tags were attached to the caudal peduncle. A few of the tags were inserted on the operculum. In the carp and buffalo the opercular bone was so hard that it could not be penetrated by the tag. Scales numbering from 4 to 6 were taken from the left side ventral to the dorsal fin and dorsal to the lateral line from each scaled fish. In addition to the tagging about one-half of the catfish taken were despined, the first spine of the dorsal fin being removed.

The fish were left in the reservoir until the following April 12, when the reservoir was drained and the fish removed.

Discussion. As soon as the fish were put into the reservoir a constant watch was kept for dead fish floating on the surface. The first dead fish, a buffalo (*Megastomatobus cyprinella*), was found eighteen days after this particular fish had been tagged and released. Three days later six more buffalo appeared on the surface, all carrying tags, but the tagged area was irritated. The last week in November five additional buffalo and one carp (*Cyprinus carpio*) were found floating on the surface, but they had all lost their tags with the exception of one buffalo. December second, another buffalo was found floating with tag gone, and January second a carp was found dead. The seven buffalo and one carp that were missing April 12 when the reservoir was drained probably died and never came to the surface or were removed by some unknown means. From table II it is noted that the carp retained their tags much better and had a lower mortality than the buffalo even though they are often considered similar fish.

The five quill back (*Carpiodes velifer*) that died were found floating each on different days between October 1 and November 15, and all of them retained their tags. The white perch (*Aplodinotus grunniens*) had a high mortality as indicated by tables I and II. Of the fifteen fish that had evidently died only three appeared on the surface. The remaining twelve fish that were missing April 12 were never seen. The photograph of *Aplodinotus grunniens* is a fair example of the condition of the greater number of fish that retained their tags at the time the reservoir was drained. The tagged area as indicated by the photograph is irritated and fungused and the

part of the caudal fin affected by the tag is much shorter than the part unaffected.

The black bull heads (*Ameiurus melas*), which are usually considered a hardy fish, had a surprisingly high mortality. At the time the reservoir was drained only one bull head retained its tag. The tagged area was severely irritated and the tag would soon have been lost, as indicated by the photograph. The one bull head that carried its tag was photographed to show the condition of the tag, which is probably similar to that in the fish which had died. The wound made by taking the spine had healed and did not leave a scar. It appears that the taking of the spines had no effect on the mortality of the fish as shown in table II, the normal bull heads having a higher death rate than the despined. The channel cat (*Ictalurus punctatus*) and mud cat (*Opladelus olivaris*) that were despined all survived the effect of the operation and the wounds healed without leaving a scar.

At no time during the winter was the reservoir frozen over for a period of more than forty-eight hours. This was prevented by the pumping of the water from the river into the reservoir to keep up the water level, since it supplies water to other ponds and the laboratory. In addition to the pumping, the winter of 1931-32 was considered very mild at Fairport. There was evidently an adequate supply of food for the fish, for when draining the reservoir a large number of crayfish of various sizes were found. Minnows that had been pumped from the river were present in sufficient quantity to serve as an adequate food supply for the bass and crappie.

A search of the literature on tagging fresh water fishes was disappointing, for the data obtained was fragmentary and incomplete. In most cases the authors merely cited that they had tagged a number of fish and that some of the tags had been returned and that it was premature to give out definite results as to the number of returned tags. Dr. David H. Thompson of the Illinois State Natural History Survey gave permission to quote him to the effect that to date he had approximately a two per cent return from 10,000 tagged fish. The earliest results obtained in literature of the tagging of fresh water fish were by Jas. R. B. Van Cleave (1898), who tagged fish at the Miltona Club situated on Lake Miltona, twelve miles north of Alexandria, Douglas County, Minnesota. He states that "During nine years I placed my German silver badge on nineteen hundred and thirty-five bass, sixteen hundred and seventy-six of which were of the smallmouth, the rest being the largemouth variety. Of the whole number captured and recorded one hundred and nine have been retaken, and re-recorded, a great many of them having been through my hands twice, many of them three times, while one was five times captured, three times in one season, being caught twice in one day by a guest who shared the boat with me." He used German silver plates one-half inch long for tags. These tags had a hole on one end and were attached to the operculum by a copper wire. M. H

Godby (1919) states the following results, "The North Canterbury Acclimatization Society annually strips a number of trout in the Selwyn River for piscicultural purposes, and takes the opportunity to tag two or three hundred fish each year with a small silver label bearing a distinctive number: at the same time particulars of length, weight and, sex are recorded. Through the kindness of the society, and of anglers who have had the good fortune to recapture fish, I have secured scales from thirteen of these fish when recaptured, and have calculated from these scales the length of each fish when tagged." In a recent publication E. L. Wickliff (1931) records the following brief notes, "A fyke net caught over 5,000 adult fish and of this number 4,000 were tagged." Later in the discussion of this same article (1931) he states, "We have a few returns to date, but that is not a cross section of the total number of fish tagged." The Twenty-Third Annual Report of the Game and Fisheries Department of Ontario (1929) states that 635 Lake Erie fish have been tagged, but it was still too premature to give any results although a few tags had been returned. In a trout tagging experiment of which several hundred trout were tagged, Snyder (1932) states, "Apparently not a single fish was injured by the tags but by the end of the month forty per cent of them had lost their tags." Later in the same paper, he states, "Undoubtedly when we released the 350 tagged bass between Fox island and the mainland there were among them some of the bass originally taken from Cahumont bay. Since then a total of twenty-two of these tagged bass have been taken and reported to us by hook and line men."

Conclusion. The author does not question that the results obtained from tagging fresh water fishes has justified the time spent. From the data obtained by this experiment and the low percentage of returned tags recorded in literature it seems apparent that for the number of fish tagged returns have been very insignificant. It seems that if a tag could be constructed that would be less irritating and less likely to be lost more significant data could be obtained. The attachment of the tag to the dorsal side of the caudal peduncle keeps it in constant motion while the fish is swimming since the caudal peduncle and caudal fin are the chief means of locomotion. The constant movement of the tag in the punctured area evidently keeps the wound made by the tag from healing. This movement produces a constant irritation until finally the wound gets so large that the tag is lost. This is evident from the condition of the tagged area shown in the photograph of *Ameiurus melas*. The scar left by the tag on fish that had lost their tags displayed the same facts. On the scaled fish a fungus growth accompanied the irritations made by the tag, but no such growth was detected on the catfish. The number 3 tag, which is a smaller tag, seems to produce another condition among the scaled fish although it gave better results with *Ictalurus punctatus*. With game fish it produced a fungused and

irritated area along the length of the tag and the part of the fin covered by the tag sloughed off.

The question also arises would an irritated caudal peduncle and a half paralyzed caudal fin have any effect on the normal movement and migration of the fish?

TABLE I

Name of Fish	Tagged	Died	Lost Tag	Tag Present	Number Spined	Spined — Died	Spined — Alive
Ameiurus melas	47	22	24	1	22	7	15
Aplodinotus grunniens	35	15	11	9			
Carpiodes velifer	10	5	5	0			
Cyprinus carpio	29	3	7	19			
Helioperca incisor	21	0	21	0			
Huro floridana	15	2	13	0			
Ictalurus punctatus	12	1	8	3	4	0	4
Megastomatobus cyprinella	35	19	12	4			
Opladelus olivaris	1	0	1	0	1	0	1
Pomoxis annularis	19	15	4	0			
Pomoxis sparoides	17	8	8	1			
Cynoperca grisea	2	0	2	0			
Total	243	90	116	37	27	7	20
Per cent		37.03	47.73	15.23		25.92	74.08

TABLE II

	Per cent of fish that retained tags	Per cent of fish that lost tags	Per cent of fish that died	Per cent of spined fish that died	Per cent of spined fish that lived
Ameiurus melas	2.12	51.06	46.81	31.81	68.18
Aplodinotus grunniens	25.71	31.43	42.85		
Carpiodes velifer	0.00	50.00	50.00		
Cyprinus carpio	65.51	24.14	10.34		
Helioperca incisor	0.00	100.00	0.00		
Huro floridana	0.00	86.66	13.33		
Ictalurus punctatus	25.00	66.66	8.33	0.00	100.00
Megastomatobus cyprinella	11.43	34.28	54.28		
Opladelus olivaris	0.00	100.00	0.00	0.00	100.00
Pomoxis annularis	0.00	21.05	78.95		
Pomoxis sparoides	5.88	47.06	47.06		
Cynoperca grisea	0.00	100.00	0.00		

Literature Cited

A Guide to Fish Marks, 1932—Extrait de Journal de Conseil de International pour l' exploration de La Mer. Vol. 7, No. 2. 1932.

Calderwood, W. L., 1901—A contribution to the life history of the salmon, as observed by means of marking adult fish. Twentieth Annual Report of the Fishery Board for Scotland, Glasgow. 1901:55-100.

Godby, M. H., 1919—A preliminary investigation of the age of growth of brown trout in Canterbury, as shown by a microscopic examination of the scales. Transactions and Proceedings of the New Zealand Institute. Vol. 51:42-67.

Snyder, J. P., 1932—Tagged smallmouth black bass in Lake Ontario. Transactions of the American Fisheries Society, 1932:380-381.

Twenty-third Annual Report of the Game and Fisheries Department of Ontario, 1929:1-122.

Van Cleave, Jas. R. B., 1898—The age of smallmouth black bass. Report of the Illinois State Fish Commissioner from October 1, 1896, to September 30, 1898.

Walton, Izaak, 1653—Compleat Angler. 246 pp. Elliot Stock, 62 Paternoster Row, E. C., London.

Wickliff, E. L., 1931—Fishery research by the Ohio Division of Conservation. Transactions of the American Fisheries Society, 1931:199-207.

Discussion

DR. GREELEY: I agree with Dr. Markus that a lot of very interesting results have been obtained by the tagging of fish, and that has been the experience in Michigan. We have recently started experiments of this same nature to determine how well the tags stay on. Brook trout were tagged, ranging in length from five and a half to ten inches; these fish had been held in one of the hatcheries through the courtesy of the superintendent, and they were checked the following April, thus giving us about six months to find out how well the tags stayed on. They have been of two types, the No. 1 fingerling tag—that is the standard; and the special fingerling tag which Dr. Hubbs has made up; I think some of you are familiar with that tag. The results certainly do show that in clipping on the gill cover you lose a terrific number of tags; less than one per cent of the fish recovered still had their tags when clipped on the gill cover. A supplementary experiment was tried with one hundred fish, the tag being pierced through at the angle of the jaw. They did not hold well at all. Another hundred were tagged in a different way, to which I would like to call attention in case those who are doing this sort of work would wish to try it. These small special fingerling tags were ringed around the jawbone instead of being pierced through any of the bone; the tag was slipped through the membrane so that it did not pierce the bone, and then it was spread somewhat to allow ample room for the jawbone to grow. That, you might say, is the same thing as the bird bander does, by surrounding one of the light bones rather than piercing through it. Fifty-four of the one hundred fish so tagged and recovered after the six months' period still had the tags on. Nine were recovered that had broken jawbones where the tag had come out. In view of the very poor returns on gill cover tagging, that is a very good recovery—fifty-four out of a hundred fish still had the tags. I believe we have learned that you cannot pierce through the bone of a fish anywhere and that the method that is most promising is that of picking a solid bone, in this case the jawbone, ringing it with the tag and spreading the tag so that it can slip up and down. Then we still have to determine how well these fish feed in the wild state. The hatchery ones fed all right and grow all right with that tag on.

DR. HUBBS: A large number of the tags which are inserted on the exterior of freshwater fishes are ordinarily lost. Some tags are returned; we have had a considerable number of returns in our Michigan experiments on trout that we had tagged more than a year previous to the time of re-

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Photograph of *Aplodinotus grunniens* (Rafinesque) displaying the condition of the tagged area after the fish had carried the tag approximately seven and one-half months. The irritation and small patches of fungus are displayed around the tag. The upper part of the caudal fin is much shorter than the lower half, which is probably due to the infection produced by the tag. The tag number of the fish is 9346.

Photograph of *Ameiurus melas* (Rafinesque) displaying the condition of the tagged area at the time the reservoir was drained. The fish carried the tag approximately seven and one-half months. This was the only one of twenty-five bull heads recovered that retained its tag. The spine inserted in the photograph above the bull head was taken from this same fish at the time it was tagged. The wound made by taking the spine had healed over and one can scarcely notice that the spine has been removed from the dorsal fin.

capture. We have had fish recaptured in the same pool where they were planted a year or more before, so that while our numerical results are few, we do obtain results over considerable periods even when this very imperfect method is employed. I believe our returns in Michigan will somewhat approximate those which David Thompson reports for Illinois, something like two per cent. No such fine returns, however, have been obtained as those that Mr. Cobb obtained in his beautiful experiment in Connecticut.

DR. BANGHAM: In respect to the four thousand fish tagged at Buckeye Lake, we did not get very many returns, but we did catch quite a number of these fish, especially bluegills and white bass, in the nets one month and two months afterwards. The percentage of loss of tagged fish was not very high. A good many crappies died, but were found floating.

DR. GREELEY: The size of the fish is a very important factor, isn't it? The trout that we tagged in the experiment I mentioned were rather small, whereas in tagging walleyes or wild rainbows, especially the former, on the gill cover, we could get returns.

DR. HUBBS: We have found it desirable to use as small a tag as possible, even on large fish. Mention has been made of some fish on which the bones of the operculum were too heavy for the tagging. We have tagged large rainbow trout in our streams in Michigan with the help of a leather punch, first punching through a round hole and then inserting the tag through or around the hole. We had a considerable number of returns from fish tagged in that way.

RETURNS FROM FISH TAGGED IN OHIO

E. L. Wickliff
Chief, Bureau Scientific Research, Division of Conservation

In 1930 the Ohio Division of Conservation, as part of its general conservation policy, started a program of tagging fish. To date 7,959 fish, comprising twenty-one species, have been tagged. These consist of largemouth black bass, smallmouth black bass, spotted bass, rock bass, bluegill, pumpkinseed sunfish, white crappie, black crappie, yellow perch, yellow pike-perch, brown bullhead, black bullhead, channel catfish, white bass, carp suckers, suckers, buffalo, brown trout and carp.

During the summer of 1930, in connection with the hydrobiological survey of Buckeye lake the following species and numbers of adult fish were measured and tagged by Dr. R. V. Bangham, formerly Temporary Biologist, and Mr. Wilbur Grimm, formerly Temporary Assistant Biologist: Bluegills, 1,829; white bass, 1,388; white crappie, 1,192; channel catfish, 283; marble catfish, 226; common sunfish, 12; carp, 9; common sucker, 6; largemouth black bass, 3; smallmouth black bass, 3; and black crappie, 3. A total of 6,505 adult fish were taken and of this number 4,954 were tagged.

Buckeye lake, a state-owned reservoir, is located about thirty miles east of Columbus and is approximately eight miles long and one-half mile wide. The fish were caught with a fyke net and tagged with No. 3 non-corrosive metal tags fastened to the gill cover with pliers. The net was lifted twice a day; morning and evening. Water temperatures ranged from 20.4° C. (68° F.) to 31° C. (88° F.).

Between June 28 and July 12 the net was set at Journal Island. It was reset in deeper water at Journal Island from August 1 to August 14. Between August 31 and September 11 the net was moved to Charleston Island, about two and one-third miles east of Journal Island.

Table 1 shows twenty-eight bluegills and three white crappies repeated at Station 1, and of the twenty-eight bluegills one repeated twice, that is it was caught three times in the same net. One bluegill repeated at Station 1 and returned at Station 2. Fishermen caught one blue gill and one channel catfish (Table 2).

At Station 2, twenty-nine white crappies, six bluegills, three white bass, three marble catfish and two channel catfish repeated. Seven bluegills, four white crappies and four white bass were repeat-returns from Station 1. Fishermen caught eleven of the fish tagged at Station 2: Four channel catfish, four marble catfish and three white bass (Table 2).

Station 3, at Charleston Island, shows repeats for eight white bass, two bluegills and one smallmouth black bass. One white bass repeated a second time, eleven were repeat-returns from Station

TABLE 1

LOCALITIES, STATION NUMBERS, DATES, SPECIES AND NUMBER OF FISH TAGGED—[1]REPEATS, [2]DOUBLE REPEATS, [3]REPEAT RETURNS AND [4]RETURNS

	Bluegills	White Bass	White Crappie	Channel Catfish	Marble Catfish	Common Sunfish	Largemouth Bass	Smallmouth Bass	Black Crappie	Carp	Common Sucker
	[1]28		[1]3								
Journal Island—Station No. 1—June 28 to July 12	[2]1										
	[4]1			[4]1							
Number of times each tagged species caught	30		3	1							
Number of fish tagged	1,409	263	293	57	18	10			2	2	4
	[1]6	[1]3	[1]29	[1]2	[1]3						
Journal Island—Station No. 2—August 1 to August 14	[3]7[5]	[3]4[5]	[3]4[5]								
		[4]3		[4]4	[4]4						
Number of times each tagged species caught	13	10	33	6	7						
Number of fish tagged	289	429	818	196	173		2	1	1		
	[1]2	[1]8						[1]1			
Charleston Island—Station No. 3—August 31 to September 11		[2]1									
	[3]1[6]	[3]11[5]		[3]1[6]							
		[3]25[6]									
	[4]1	[4]4									
				[4]2	[4]1						
Number of times each tagged species caught	4	49		3	1			1			
Number of fish tagged	131	676	81	30	35	2	1	2		7	2

[1]Tagged fish retaken in the net at the same place.
[2]Tagged fish retaken twice in the net at the same place.
[3]Fish tagged from one net and retaken at another station number.
[4]Tagged fish taken by hook and line.
[5]Tagged at Station 1.
[6]Tagged at Station 2.

TABLE 2

Tag Numbers of Buckeye Lake Fish, Dates Fish Tagged and Caught by Fishermen, Distance Travelled and Direction

Tag number	Species	Date tagged	Date caught	Miles Travelled	Direction
1389	Channel Catfish	7/7/1930	8/12/1930	0.0	
2219	Channel Catfish	8/2/1930	7/13/1933	.25	North
2222	Channel Catfish	8/2/1930	5/17/1931	1.7	Southwest
2492	Channel Catfish	8/3/1930	11/11/1930	.5	East
2738	Channel Catfish	8/4/1930	10/ 7/1931	.5	East
4057	Channel Catfish	9/1/1930	3/21/1931	.02	East
4203	Channel Catfish	9/3/1930	11/11/1931	3.	West
2045	Marble Catfish	8/1/1930	5/10/1933	2.1	East
2486	Marble Catfish	8/3/1930	4/15/1931	1.2	West
2957	Marble Catfish	8/7/1930	6/16/1933	1.5	Southwest
3833	Marble Catfish	8/8/1930	8/23/1930	2.1	East
4044	Marble Catfish	9/1/1930	4/4/1931	.25	East
2093	White Bass	8/1/1930	5/24/1931	.6	Northwest
2428	White Bass	8/3/1930	8/30/1930	.3	North
3348	White Bass	8/9/1930	8/12/1930	1.5	Southwest
4372	White Bass	9/9/1930	5/20/1931	1.2	East
4423	White Bass	9/9/1930	5/22/1931	No data	
4522	White Bass	9/9/1930	6/6/1931	.7	Northwest
4702	White Bass	9/10/1930	5/9/1931	.7	Northwest
513	Bluegill	7/1/1930	7/16/1930	1.	Northeast
4726	Bluegill	9/10/1930	10/9/1930	1.1	Northwest

1, and twenty-five were repeat-returns from Station 2. One channel catfish and one bluegill were repeat-returns from Station 2. Fishermen reported catching four white bass, two channel catfish, one marble catfish and one bluegill (Table 2).

The total number of tagged fish caught by hook and line was twenty-one. Of this number seven were caught in 1930; eleven in 1931, and three in the spring of 1933 (Table 2).

Of the 4,954 fish tagged, twenty white crappies, one bluegill and one white bass were reported found dead or in a weakened condition in 1930. All dead or weakened fish except one white crappie were found in August. Ten of the twenty August crappies, the bluegill and the white bass were removed from the net.

These data show the following percentages for the total number of times each species was retaken after tagging: Bluegill, 2.5; white crappie, 3.0; channel catfish, 3.5; marble catfish, 3.5, and white bass, 4.2. Twenty-one of the total of 108 fish taken (163 taken and retaken) were caught by fishermen. One marble catfish (tag number 2,045) was tagged on August 1, 1930, repeated August 2, 1930, and on May 10, 1933, was caught on hook and line two and one-tenth miles east of where it was tagged. Two channel catfish were tagged on August 2, 1930; one was caught on hook and line May 17, 1933, and the other on July 13, 1933.

Three white bass tagged September 9, 1930 were all taken by angling during the spring of 1931 (table 2). Channel and marble catfish seem to be more susceptible to hook and line fishing than white crappies or bluegills unless the latter species lose their tags. The catfish and the white bass appear to school and wander around the lake more than the crappie and bluegill. Except white crappies, tagging and live netting of game fish in a small lake offers possibilities for determining fish populations, movements and rates of growth.

During 1931 and 1932 Mr. T. H. Langlois, Chief of the Bureau of Fish Propagation; Mr. M. B. Trautman, Assistant, Bureau of Scientific Research; Mr. J. W. Stuber, Chief of the Bureau of Education; and the writer, tagged 3,005 fish. Practically all of these were fish planted in streams. The following, largely adults, were taken in trap nets and seines from Lake Erie, tagged and planted almost entirely in our streams: smallmouth bass, seven hundred seventeen; channel catfish, six hundred eighty-two; rock bass, five hundred thirty-three; brown and black bullheads, two hundred seventy; largemouth bass, one hundred forty-four; pumpkinseed, thirty-two; spotted bass (southern Ohio) one; ringperch, one. Returns for each species are as follows: carp, one or 100 per cent; rock bass, fifteen or 2.8 per cent; channel catfish, fourteen or 2.1 per cent; smallmouth bass, ten or 1.4 per cent; largemouth bass, one or .7 per cent; black bullhead, one or .4 per cent. Returns from fishermen (table 3) are very interesting and from the stand-

point of stocking open a field of research worthy of more intensive work. Table 3 is self-explanatory. All returns with complete data show a very definite downstream migration, or very little movement, irrespective of the time of year planted. During the downstream migration low dams did not seem to be a serious obstacle, although several fish were caught at dams. The carp successfully passed through the heavily polluted waters of the lower Maumee river and upper Maumee bay. Smallmouth bass and rock bass planted above Dayton in the Stillwater, Miami and Mad rivers and taken in the Miami river below town or in the Ohio river encountered pollution of several kinds, and dams from five to twelve or more feet in height. Returns from over the state show that smallmouth bass may migrate downstream over two hundred miles in less than three months; rock bass seventy-five miles in four months? (record incomplete); and channel catfish eighty-four miles in three months? (record incomplete).

Hatchery fingerlings during October and November, 1931, were marked with fingerling tags as follows: smallmouth bass, five hundred forty-one; brown trout, eighty-three; rock bass, one. The smallmouth bass and rock bass were all under the legal length, and most of the brown trout were undersized fish. To date one return has been received (tag number 50,305).

TABLE 3

Migration of Ohio Fishes

Tag No.	Species	Length in inches	County released	Stream	Date planted	Date taken	County caught	Stream	Distance travelled in miles	Direction of Movement
5028	Largemouth	12 1-5	Preble	Twin	10/15/31	11/ 2/31	Preble	Twin	6.5	Downstream
6016[1]	Smallmouth	14	Guernsey	Brushy Fork	10/24/31	4/21/32	Muskingum	Muskingum	65.	Downstream
6027[2]	Smallmouth	10	Guernsey	Brushy Fork	10/24/31	5/29/32	Washington	Muskingum	140.	Downstream
6073[3]	Smallmouth	12 1-5	Guernsey	Brushy Fork	10/24/31	4/25/32	Muskingum	Muskingum	55.	Downstream
6099[4]	Smallmouth	11 3-5	Guernsey	Brushy Fork	10/24/31	6/21/32	Muskingum	Muskingum	55.	Downstream
6159[5]	Smallmouth	12 2-5	Montgomery	Stillwater	11/ 6/31	3/ 3/32			205.	Downstream
6179[6]	Smallmouth	13 1-2	Montgomery	Stillwater	11/ 6/31	2/27/32			95.	Downstream
6252[7]	Smallmouth	10	Montgomery	Stillwater	11/ 6/31	11/11/31	Butler	Miami	35.	Downstream
5187	Smallmouth	14	Wyandot	Sycamore	10/23/31	4/23/32	Wyandot	Sandusky	.5	Downstream
5320[8]	Smallmouth	11 2-5	Wyandot	Sycamore	10/23/31	4/24/32	Seneca	Sandusky	10.	Downstream
5099[9]	Smallmouth	13 3-4	Hardin		10/23/31		Hardin			
6316	Rock Bass	8 1-2	Montgomery	Mad	11/ 6/31	11/ 8/31	Montgomery	Mad	1.	Downstream
6323[10]	Rock Bass	7 1-5	Montgomery	Mad	11/ 6/31	4/ ?/32			75.	Downstream
6324	Rock Bass	9 4-5	Montgomery	Mad	11/ 6/31	?	?	Miami		
6353[11]	Rock Bass	8	Montgomery	Mad	11/ 6/31	11/13/31	Montgomery	Mad	1.	Downstream
6371[12]	Rock Bass	8 4-5	Montgomery	Mad	11/ 6/31	11/ 8/31	Montgomery	Mad	1.	Downstream
6200	Rock Bass	7 4-5	Montgomery	Stillwater	11/ 6/31	?	?	Miami		
6225[13]	Rock Bass	8 4-5	Montgomery	Stillwater	11/ 6/31	11/ 9/31	Montgomery	Miami	.25	Downstream
6256	Rock Bass	8 3-4	Montgomery	Stillwater	11/ 6/31	11/ 9/31	Montgomery	Stillwater	same place	
6569[14]	Rock Bass	8 3-5	Montgomery	Stillwater	11/ 6/31	3/30/32	Montgomery	Miami	12.	Downstream
6617[15]	Rock Bass	7 3-5	Montgomery	Stillwater	11/ 6/31	4/27/32	Butler	Miami	35.	Downstream
6405	Rock Bass	9	Montgomery	Miami	11/ 6/31	11/ 8/31	Montgomery	Miami	Same place	
6528[16]	Rock Bass	7 3-5	Montgomery	Twin	11/ 6/31	4/27/32	Butler	Miami	15.	Downstream
5266[17]	Rock Bass	9 3-5	Wyandot	Sycamore	10/23/31	6/ 5/32	Seneca	Sandusky	30.	Downstream
5295	Rock Bass	7 7-8	Wyandot	Sycamore	10/23/31	4/23/32	Wyandot	Sandusky	.5	Downstream
6498[18]	Rock Bass	8 3-5	Montgomery	Twin	11/ 6/31	4/ ?/32			50.	Downstream
51647	Channel Cat	12	Wayne	Killbuck	5/26/32		Wayne	Killbuck	5-9.	Unknown
51670[19]	Channel Cat	12 1-5	Wayne	Killbuck	5/26/32	6/14/33	Muskingum	Muskingum	100.	Downstream
51689	Channel Cat	11	Wayne	Killbuck	5/26/32	Before 6/10/32	Wayne	Killbuck	5-9.	Unknown
51690	Channel Cat	10 4-5	Wayne	Killbuck	5/26/32	Before 6/10/32	Wayne	Killbuck	5-9.	Unknown
53103	Channel Cat	12 1-5	Wayne	Killbuck	5/26/32	Before 6/10/32	Wayne	Killbuck	5-9.	Unknown
53110	Channel Cat	9 2-5	Wayne	Killbuck	5/26/32	8/ ?/32	Muskingum	Muskingum	84.	Downstream
53112	Channel Cat	13 3-5	Wayne	Killbuck	5/26/32	Before 6/10/32	Wayne	Killbuck	5-9.	Unknown
51203[20]	Channel Cat	11	Warren	Caesar	10/16/31	2/ 2/32	Warren	Little Miami	20.	Downstream
51273[21]	Channel Cat	10 2-5	Warren	Caesar	10/16/31	6/15/32	Warren	Little Miami	20.	Downstream
51301[22]	Channel Cat	10 2-5	Warren	Caesar	10/16/31	6/15/32	Warren	Little Miami	20.	Downstream
51347[23]	Channel Cat	11	Warren		10/16/31	5/13/32	Clermont	Little Miami	30.	Downstream
53263	Channel Cat	12 2-5	Morrow	Kokosing	5/26/32	8/20/32	Knox	Kokosing	15.	Downstream
53295	Channel Cat	13 1-5	Morrow	Kokosing	5/26/32	6/ ?/32	Morrow	Kokosing		Near where planted
53417	Channel Cat	10 4-5	Marion	Scioto	5/27/32	7/ 2/32	Delaware	Scioto	20.	Downstream
53182	Black Bullhead	8	Wayne	Killbuck	5/26/32	6/15/32	Wayne	Killbuck	5.	Unknown
5587[24]	Carp [fingerling	11 3-4	Lucas	Maumee	6/ 6/31	11/ 2/31	Lucas		25.	Downstream
50305[25]	Smallmouth	8 1-2	Washington	Wolf	10/20/31	6/19/32	Washington	Muskingum	20.	Downstream

53295	Channel Cat	13	1-3	Morrow						8.	
53417	Channel Cat	10	4-5	Marion	Scioto	5/27/32	7/ 2/32				
53182	Black Bullhead	8		Wayne	Killbuck	5/26/32	6/15/32	Wayne	Killbuck	25.	Downstream
55872[24]	Carp [fingerling	11	3-4	Lucas	Maumee	6/ 6/31	11/ 2/31	Lucas			Downstream
80305[25]	Smallmouth	5	1-2	Washington	Wolf	10/20/31	6/19/32	Washington	Muskingum	20.	

REMARKS*

[1]Movements obstructed by two dams each about eight feet high.
[2]Caught at Marietta dam. Movements obstructed by 10 other dams from eight to twelve feet high.
[3]Caught at Ellis dam. Movements obstructed by one other dam eight feet high.
[4]Caught twice at Ellis dam, the second time on June 23, 1932. Movements obstructed by one other dam eight feet high.
[5]Caught at Sugar Grove, Ky., in Ohio River. Movements obstructed by nine dams five to twelve feet high.
[6]Caught in Ohio River at Rising Sun, Ind. Movements obstructed by seven dams five to twelve feet high.
[7]Caught at hydraulic head race and released. Movements obstructed by six dams five to twelve feet high.
[8]Movements obstructed by two dams each six feet high.
[9]Planted and caught in lake.
[10]Caught in Ohio River below Aurora, Ind. Movements obstructed by six dams five to twelve feet high.
[11]Movements obstructed by one dam six feet high.
*Data on dams probably incomplete.

[12]Movements obstructed by one dam six feet high.
[13]Caught and released.
[14]Movements obstructed by one dam seven feet high.
[15]Movements obstructed by five dams five to twelve feet high.
[16]Movements obstructed by two dams each five feet high.
[17]Movements obstructed by three dams each six feet high.
[18]Caught in Ohio River below Aurora, Ind. Movements obstructed by three dams each five feet high.
[19]Movements obstructed by one dam eight feet high.
[20]Caught at Kings Mill dam. Movements obstructed by two dams five and seven feet high.
[21]Caught at Kings Mill dam. Movements obstructed by two dams five and seven feet high.
[22]Caught at Kings Mill dam. Movements obstructed by two dams five and seven feet high.
[23]Movements obstructed by five dams five to eight feet high.
[24]Caught in Lake Erie crib net.
[25]Movements obstructed by one dam twelve feet high.

A METHOD OF COLLECTING STATISTICS OF MARINE SPORT CATCHES IN CALIFORNIA

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Marine sport fishing is a popular form of recreation in southern California. Catering to salt-water anglers is an important business. Several companies and individuals do little else save provide means whereby sportsmen may enjoy a day's, week's or even a month's fishing. A variety of types of fishing are offered to anglers at nominal cost or at no cost. The facilities for fishing are as follows: barges, party boats, charter boats, piers, skiffs, and shore (beaches, rocks, bays).

The barges are the hulls of old sailing vessels or flat scows. They are anchored several hundred yards to three miles offshore from the various beach towns. Small boats run on regular schedule between the barges and the piers at the nearest towns. The price of the ticket for barge fishing includes transportation to and from the barge, a supply of bait (dead or live anchovies or sardines) and in some cases the use of a pole and line. Most of the larger barges have overnight accommodations and lunch rooms. Aboard these barges, the fisherman may spend a few hours or a few days, returning to shore with his catch when he desires. The season extends from March to October, but some barges remain anchored throughout the winter to cater to the most enthusiastic anglers. (These barges average 70 people per day throughout the season and often handle 250 people on one day).

"Pleasure party boats" go out on regular schedule every day to nearby fishing grounds. These boats remain on the grounds either for a half day (four hours) or a full day (six to seven hours). The fee is more than for barge fishing and includes passage to the fishing banks, a supply of live bait and sometimes the use of tackle. The boats are capable of accommodating an average of about 30 fishermen. The advantage of the party boat over the barge is that usually a greater variety of fish is available, as the boats can go where certain kinds of fish are biting best.

Boats for charter by the day or half day are also available for use of private parties or individuals. The cost of trips on these boats is much higher than for the other types.

Most of the piers are available to fishermen at no cost. In some instances where a company has a lease on a pier, a charge is made for fishing from the best portion—usually the extreme end. On most of the piers there are concessions for selling tackle and live and salted bait.

Skiffs can be rented at various towns for fishing close to shore or in sheltered bays.

Many people prefer to fish from shore, on sandy beaches, from rocks or breakwaters, or from the banks of bays and sloughs. For the convenience of these anglers there are bait and tackle shops at every coastal town.

This business of catering to marine sport fishermen has grown by leaps and bounds during the last eight years. Every year sees more boats and barges being used along the 200 miles of coastline from San Diego on the south to Santa Barbara on the north. During the summer of 1933, there were approximately twenty-five full time barges, forty party boats, fifteen piers (with bait accessible), and thirty charter boats operating along the southern California coast. In addition there were other barges that operated for brief periods, several boats that took out parties occasionally and a number of piers from which people fish but where bait is not sold. Party boats and charter boats have been available for several years at Monterey Bay towns in northern California, and recently barges have made their appearance in those waters.

It could be seen that thousands of fishermen made use of the facilities offered them and that they caught large numbers of fish. Many of the species they catch are also taken by commercial fishermen, and from time to time controversies have arisen as to whether the sportsmen or the commercial operators are taking the greater part of the total catch. The commercial catch is known and has been recorded for many years,* but until recently little was known of the magnitude of the sport catch. It became the duty of the California Division of Fish and Game to determine the quantities of fish caught by marine sport fishermen in order that its conservation program be administered wisely. With an adequate knowledge of the extent of the fishery, it would be possible to make recommendations based on facts, to pass judgment on proposed legislation, and to carry on studies of the utilization of the various species comprising the sport catch in the same way that analyses of the commercial catch are made. Consequently, in March, 1932, the Division inaugurated a system to collect statistics on the marine sport catch.

The employees of the various companies and individuals catering to fishermen are in constant personal contact with about seventy-five per cent of all the salt-water anglers. Because of this personal contact and because the pleasure fishing firms are concentrated at good points of landing, such as piers, we have been able to devise a comparatively simple and at the same time inexpensive method for collecting good estimates of the marine sport catch. G. H. Clark and L. G. Van Vorhis have developed and carried out the system.

After some preliminary trials and discussion with the operators, we had printed two forms: Form *A*, (size 4½ x 9½ inches) for use on pleasure party boats, charter boats and piers; and Form *B*, (size

*Scofield, W. L. Comments on fisheries statistics collected in California. American Fisheries Society, Transactions, Vol. 62, pp. 94-99, 1932.

$8\frac{1}{2}$ x 11 inches) for use on barges. These forms are to be filled out daily by the operators of the various units.

Form *A*, lists the names of the commonly caught species of fish, opposite which the number and approximate total weight of each species can be recorded. This form when used for a boat shows date, name of boat, number of hours fishing, locality fished, and number of fishermen. The captain obtains the catch statistics from the fishermen on the homeward trip. When used on a pier this form shows date, name of pier, approximate number of hours open, and average number of people fishing throughout the day.

Form *B*, is larger because of the greater numbers of people that patronize the barges and because of the method used by the operators in estimating the catches. The master of the barge stands at the ladder when a shoreward bound boat is about to depart, counts the people leaving, and estimates the amounts of the different kinds of fish caught by those leaving. The following appear at the top of Form *B*, which is a sort of daily work sheet: *date, name and locality of barge,* and the *number of fishermen* in the morning and in the afternoon. Below these appear vertical columns headed by the names of the species commonly taken, with spaces for the number of fish and total weight under each species' heading.

These daily records from the boats, barges and piers are collected by the California Division of Fish and Game and summarized into monthly tables by species, showing number of fish and total weight in pounds, as well as the amount of effort expended by the fishermen. The records of each boat, barge and pier are kept separately and the operators of each unit are sent a monthly report of their own records after they have been tabulated by the Division. These reports are often used for advertising purposes by the fishing companies.

We realize of course that these records are not exact to the pound, but they are accurate estimates. Considering that heretofore we could only base estimates on casual observation and hearsay, these statistics give us a good conception of the amounts of fish taken by marine sport fishermen in these waters. The pier records are the least accurate because the concessionaire can not see all the fish taken but can only give estimates. The barge records are not as accurate as those of the smaller boats because of the difficulty of dealing with large groups of people. The records of the party and charter boats are most accurate because of the smaller number of fishermen and relatively ample time for the captain to obtain the required statistics.

The collection of these statistics depends solely upon the operators of the various piers, boats and barges. We have made personal contact with almost every person or firm engaged in this line of business in order to enlist their assistance and cooperation. No force of law has been used and all response has been voluntary.

These men see the need and the personal advantages of keeping fairly accurate catch records. A number of them have aided us in every way and to them we owe a great deal. We have particularly cautioned the operators about over-estimates and have stated we would prefer under-estimates. We realize that unscrupulous operators may for advertising purposes exaggerate their catches, but we feel fairly certain that such has not been the case. We have compared the records of boats owned by different firms and found that the recorded catches of similar boats, carrying approximately the same number of fishermen, do not vary greatly.

We have not been able to obtain returns from all operators but we receive a fair sample and from different localities. Knowing the number of boats, piers and barges in operation and having a fair sample to date of the sport catch, it is possible to give a good estimate of the catch and the number of fishermen for a season. The following figures are for a season, March to October, based on a twenty-five per cent sample and weighted by the number of barges, piers and party boats in operation (not including charter boats or small piers):

No. of fishermen	700,000
No. of fish caught	4,050,000
Lbs. of fish caught	7,275,000

The size of the sport catches of some of the more desirable and important species, which are also taken by commercial fishermen, are as follows:

Species	Number	Pounds
Barracuda	737,000	2,345,000
Bonito	227,000	730,000
California Halibut	148,000	783,000
Pacific Mackerel	2,385,000	2,355,000
Yellowtail	13,000	170,000
All other species	540,000	892,000

It must be pointed out that the 700,000 fishermen are not different individuals, but represent the number of people handled, as about three-fourths of the anglers fish a number of times in a season.

The total sport catch of 7,000,000 pounds is about five per cent of the total annual commercial catch for the same area. However, sardines comprise eighty-two per cent of the commercial catch. Excluding sardines, the sport catch amounts to about twenty-eight per cent of the commercial take. The sport catch equals fifty-four per cent of the market yield exclusive of cannery fish.

The sport catch figures do not include the large amounts of young sardines, anchovies and other fish that are taken for use as bait by sport fishermen.

In addition to obtaining total catch figures, our system will

enable us to record any changes in availability of the various species of fish to the fishermen. Because the amount of time expended by fishermen on barges and piers is relatively constant from year to year, and knowing the number of fishermen, we will be able to calculate the fish yield per unit of effort from one season to another. The catch per unit of effort put forth by fishermen on party and charter boats can be calculated readily because the exact number of passengers and hours of fishing are recorded with the catch. It is not absolutely essential to have figures on the entire catch of sport fish in order to determine accurately the trend of fluctuations. With an adequate representative sample, it is possible to ascertain the catch per unit of effort more accurately than the total catch.

From our past experience in dealing with the collection of commercial catch statistics, we have found that in order for such a system to be successful it must be followed up, as no system will carry on by itself. However, by gradually introducing the system and educating the people concerned as to its use and necessity, it is possible to install a method that will give good working results in a relatively short time.

Discussion

MR. FARLEY: I wonder if I might make one or two comments on that paper?

THE PRESIDENT: We shall be glad to have you do so.

MR. FARLEY: It is with respect to a situation that perhaps is common in a good many states. In California we have rather complete data on our commercial fisheries, by the force of proper legislation and proper control of that fishery. But quite often the catch of sport fish covering both the field of game fishing and the field of commercial fishing, becomes of prime importance and even exceeds the commercial catch. So if we are to keep a proper finger on the pulse of the fishery, we should know more about the sport catch than we do. Beginning with our commercial fisheries laboratory, a start was made on this particular problem, dealing particularly with our ocean sport fishing. For instance, in the case of the barracuda, this fish is taken as a sport fish in some cases in quantities exceeding the amount taken as a commercial or market fish. Likewise with the sea bass and the striped bass. Our commercial fisheries laboratory, with the double purpose of getting information of prime importance to the commercial fishery and making the commercial fishing problem a common problem with that of the sport fisherman and thus gain the cooperation of that particular group in the state, made a start on this plan of gathering data from the sport fisherman. We drew from the experience of Michigan in its trout work and of other states where similar efforts had already been made. The results are quite satisfactory, and this paper, as you will note when you have an opportunity to review it, gives the preliminary results of that particular research. But the thing I want to comment on is the very great desirability of tying up this problem of the com-

mercial fisheries with the problem of the sport fisherman and getting these two groups to work together in that respect. In our state, where the commercial fishing industry is of such great importance, and where it so much overlaps the interests of the sport fishermen, as evidenced in the striped bass and salmon and other fishes, that has been lacking in the past, and there has been a lack of confidence on the part of the sport fishermen in the data that has been gathered by the commercial fishing organizations. I believe such efforts as these will go a long way towards ironing out these differences and getting the sportsmen and the commercial fishermen together on common ground when we seek proper legislation and when we have such conferences as we have in Sacramento. I commend this problem to those of you who are scientists and ask you to join up the interests of the commercial fishermen with those of the sportsmen.

The President: Thank you, Mr. Farley.

Mr. Farley: May I make one further comment? Last year you had presented to you a paper on the Commercial Tabulation of Data as Carried on in California. I brought with me samples of the statistical work which we are doing there. We believe we have something that is just a little bit ahead of anything that is being done anywhere else in the other states. If these reports are of interest to you—every pound of fish, every dollar that is spent in buying fish, is a matter of record with us—I shall be glad to discuss them with you at the close of the session.

THE VITAMIN REQUIREMENTS OF GOLDFISH AND CHANNEL CAT

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Fish nutrition, as a science, is a comparatively new field and, as yet, most of the experimental work has been done with trout. When trout culture was first started nearly every hatchery used liver for feeding purposes. It was low in price and produced good growth. But, in recent years, the nutritional value of liver in the human diet has received much attention and, as a consequence of the increased demand for liver as a human food, it has become necessary for fish culturalists to find some adequate substitute.

So far as is known, all vertebrates and many invertebrates require vitamins in their diets, although the same vitamins are not required in every case. Thus vitamin C, the antiscorbutic vitamin, while essential to man or the guinea pig, is not needed in the diet of the rat. Pending carefully controlled experiments upon the vitamin requirements of fish, it must be kept in mind that some vitamins essential to the health of mammals may not be necessary to fish; that some vitamins not needed by mammals may be essential to fish; and that different species of fish may have different vitamin requirements.

Davis and James (1924) found that carp and possibly trout require vitamins A, B, and C for proper growth.

A year later Goldberger and coworkers (1925) first postulated the existence of two separate dietary factors in what had previously been known as vitamin B, and in 1926 they accomplished the separation of an antineuritic and a growth producing factor by means of their different behavior to heat. Subsequently the committee on vitamin B terminology of the American Association of Biological Chemists (1929) voted to recommend that the term "B" be restricted to designate the more heat-labile antineuritic factor, and that the term "G" be used to denote the more heat stable factor which has also to do with maintenance and growth.

As a result of extensive experiments, McCay, Bing and Dilley (1927) found that trout need a protein level over 10 per cent for normal growth, but that the addition of more than 25 per cent had no effect upon the rate of growth. These workers also found that the addition of vitamins A, B, or D to the diet apparently had no effect upon the growth of trout. This statement can not, however, be interpreted to mean that the fish do not require these vitamins, because highly purified food stuffs were not used in the diets.

In a later paper, McCay and Dilley (1927) announce a factor which they have found in raw meat, which is essential for normal

growth of trout, and which is distinct from any known vitamin. They confirm the work of Richet (1925) and Laufberger (1926) who showed that raw meat contains growth promoting properties not found in meat which has been extracted with alcohol and ether, and further show that the growth promoting factor is destroyed by cooking or drying. They designate this dietary factor as "Factor H."

Davis (1927) in five years of hatchery work with trout, found that beneficial results were obtained in every case where cod-liver oil and yeast were added to the diets of rainbow trout. Brook trout, on the other hand, showed no benefits from the addition of these substances. It seems, therefore, that each species of fish presents an individual nutrition problem.

Thompson (1928) found so called "knot head," a condition of malformation of the skull bones, prevalent in carp taken from the middle Illinois River, and suggests that this malady may be comparable to mammalian rickets; and result from the replacement of chlorophyll bearing plankton by non chlorophyll bearing forms in the diets of the fish in this heavily polluted section of the river.

The present investigation was suggested by observations made during the summer of 1927 at the State Fish Hatchery at Pratt, Kansas. The spotted channel cat fish (*Ictalurus punctatus* Raf.) is raised by the trough method at the Kansas hatchery. The culturalist had planned to feed the young cat fish live natural foods, mostly Daphnia, which were raised in large tanks constructed for the purpose, and black fly larvae collected from swift water at the drains of the ponds. With the retardation of reproduction of these forms caused by the onset of hot weather, this supply of food was soon depleted. The first substitute tried was dried buttermilk powder. The young fish ate this diet readily, however serious pathological symptoms soon developed resulting in high mortality. The chief observable symptom of the malady was extreme nervousness and loss of motor coordination. Upon any slight vibration, such as rapping against the troughs, the affected fish would "throw fits," "tail spins," and swim in circles on their backs. This condition was remedied and further mortality checked by the addition, to the diet, of vitamin rich foods, including yeast, cod liver meal, liver, canned tomatoes, fresh blood, and duckweed.

Since the loss of motor control noted in the fish was suggestive of conditions described as occurring in animals suffering from beriberi, and since nothing could be found in the literature concerning the vitamin requirements of cat fish, the authors decided to undertake controlled experiments to determine the vitamin requirements of these fish. Because of the limited number of rearing troughs available, the study was limited to the vitamins known as B, G, and D.

Goldfish are able to live for long periods on vitamin deficient

diets, such as many of the commercial rice wafers. It is noticeable, however, that goldfish kept in aquaria do not attain the size of those given the freedom of the ponds where they are able to forage. To what extent the difference in growth is due to limited space, and to what extent it is due to improper food, is not known. For this reason, and also to ascertain whether there might be a difference in vitamin requirement between the goldfish, which is largely vegetarian, and the cat fish, whose natural diet is largely animal, both the goldfish and the channel cat were included in these experiments.

Methods

The fish used in these experiments were the common uncolored gold fish (*Carassius auratus* Linnaeus), obtained from the Grassyforks Fish Hatcheries at Martinsville, Indiana, and the spotted channel cat fish, (*Ictalurus punctatus* Raf.), supplied by the Kansas State Fish Hatchery at Pratt, Kansas.

The fish were kept in wooden troughs constructed for the purpose. These troughs were six feet long, one foot wide, and ten inches deep. Water flowed from a faucet into each trough at one end, and out at the other end from a pipe inserted near the bottom. The water was from the supply of Kansas State Agricultural College, and was kept at a depth of about eight inches in each trough. Fifty catfish and one hundred goldfish were placed in each trough, separated from each other by a screen wire partition. About a third of the trough, nearest the inlet, was given over to the catfish, and the goldfish had the remainder of the trough near the outlet. Waste material was siphoned from the troughs each day. Once a week the fish were removed and the troughs scrubbed with hot water. This controlled, to some extent, the growth of fungus.

The goldfish experiment was started February 15, 1929, and the catfish March 17, 1929. Because of severe weather it was impossible to obtain the catfish at an earlier date.

At the beginning of the experiment the fish were weighed and measured. Thereafter they were measured once a month. The distance from the most anterior point to the base of the caudal fin, measured with a pair of dividers, was considered as the length of the fish. Weighings were not made of individual fishes, however each group of fish was weighed each week. Had all of the fish lived, these weights might have given some significant results, but, as some fishes died in each group, and the death of the smallest or the largest fish in a group might have more effect upon the average weight of the group than would a week's growth, the results of the weighings were not considered dependable, and these data have been omitted.

The following diets were fed to the fish:

DIET NO. 1. —B —G

Vitamins B and G lacking

Polished rice flour	68 gms.
Vitamin-free casein	18 gms.
Crisco	6 gms.
Hogan's salt mixture	4 gms.
Cod liver oil	4 gms.
Water	150 cc.

DIET NO. 2. —B +G

Vitamin B lacking, G present

Diet 1 plus 12 gms. brewer's yeast autoclaved at 15 lbs. steam pressure for 150 minutes.

DIET NO. 3. +B +G CONTROL

Adequate synthetic diet

Diet 1 plus 12 grams fresh brewer's yeast.

DIET NO. 4. BUTTERMILK DIET

Diet 1, but with the casein substituted by 18 gms. dry buttermilk powder as a source of vitamins B and G.

DIET NO. 5. + MEAT

Same as diet 4 plus 12 gms. fresh brewer's yeast and 60 gms. fresh ground liver.

DIET NO. 6. —D

Vitamin D deficient

Yellow corn meal or oatmeal	68 gms.
Crisco	10 gms.
Hogan's salt mixture	4 gms.
Vitamin free casein	18 gms.
Brewer's yeast	10 gms.
Grapefruit juice	25 cc.
Water	200 cc.

DIET NO. 7. +D CONTROL

Adequate synthetic diet

Same as diet 6 but with 4 gms. of the crisco substituted by 4 gms. cod liver oil.

The cereal, protein, salts, crisco, and water, were mixed together and cooked in a double boiler to form a thick mush or dough. After cooling, the vitamin containing ingredients were added. The casein used was treated with alcohol by the Sherman process, (Sherman, 1925) to remove vitamins B and G. The salt mixture used was that recommended by Hogan (1925). It contains the necessary salts in proper proportions and in available form. Casein was used as a source of protein, crisco as a source of fat, yeast for vitamins B and G, grape fruit juice for vitamin C, and cod liver oil for vitamin D.

In diets 6 and 7, corn meal was first used as the cereal, but the food had a tendency to fall apart and mix with the water and was not eaten readily by the fish, so oatmeal was substituted for the corn. In diet 5, the meat containing diet, rice flour was first used making the diet similar to those used in the vitamin B and G experiments. After May 4, when the B and G series was discontinued, the fish on diet 5 were continued as a check to diets 6 and 7, and oatmeal was then substituted for rice flour.

The fish were fed twice daily. The group that ate the least was taken as a criterion as to the amount to feed all, in order to eliminate differences due to palatability of foods.

Since the symptoms produced by vitamin deficiency in rats are distinctive and have been much studied, it was thought best to check the vitamin content of the diets by feeding them to young rats. Five male white rats of the same litter and five weeks old were fed diets 1 to 5 inclusive for a period of six weeks, and two brothers of a different litter six weeks old were fed diets 6 and 7 for the same period. After a brief initial gain in weight, the rat on diet 1 began to lose weight until, by the end of a month, it was 6 grams lighter than at the beginning of the experiment. Upon transfer to diet 3 it promptly began to gain, thus confirming the assumption that its stunting was due to deficiency in vitamin G. The rat

on diet 2 made normal gain in weight and failed to develop the symtoms characteristic of lack of vitamin B. Since, however, the rats were five weeks old at the beginning of the experiment, which continued for only five weeks, it is probable the time was insufficient for these symptoms to develop. The rat on diet 6 (lacking vitamin D) made normal growth, but an X-ray photograph of its skeleton, as compared to that of its control, showed poor ossification of the greater trochanter, the ends of the humerus and ulna, the ends of the long bones of the foot, and a characteristic indefiniteness of outline at the connection of ribs and sternum, thus indicating that a condition of rickets existed. The other rats made approximately equal gains, the one on diet 5 (containing meat) showing the better growth.

Data

The growth of fish on the various diets is shown in the following tables and graphs. The experiment on goldfish was discontinued May 4th, because, by that time, the ovaries of the females were becoming distended with eggs, and the fish were showing breeding activity. As growth in length is normally checked during the breeding season, and as the deposition of eggs by even a few fish would completely vitiate further results by furnishing additional dietary factors to the group, the experiment could not be continued. Due to an accident which resulted in the loss of the catfishes from two tanks, the experiments on vitamins B and G were all terminated May 4, although the work on vitamin D was continued until July 6.

TABLE 1. Goldfish

Diet	No. survived	Av. length as mm.	Av. gain as mm.	% gain
1. —G —B	74	53.21	2.52	4.73
2. —B	94	53.17	2.9	5.45
3. +G +B control	94	53.05	3.1	5.85
4. Buttermilk	89	52.23	3.14	6.01
5. Meat	94	54.26	3.45	6.36
6. —D	87	53.93	1.07	1.99
7. +D control	76	53.13	2.5	4.71

A scrutiny of Table 1 and Fig. I shows, at at glance, that vitamin D is essential for the growth of goldfish. In fact, after the first three weeks, the fish lacking this dietary factor made no further growth, the apparent increase in length being due to the death of the smaller individuals. The fact that the vitamin D control (Diet 7) made less growth than the other controls (Diets 3, 4, and 5) is probably due to the fact that the fish ate the food containing rice (first 5 diets) more readily than the food containing other cereals, so less of their ration was wasted.

The data on vitamins B and G are much less conclusive. Except for the D-deficient ration, the diet lacking the vitamins of yeast gave the poorest growth. It also resulted in the highest mortality.

Although the figures here presented are far from conclusive, the authors are of the opinion that vitamin G is probably necessary in the diet of the goldfish since the fish on diet 1 appeared much more susceptible to fungus than those to which vitamin G. was furnished. Although all groups were subject to fungus attacks, and continual effort was necessary to keep it in check, it was only in group 1 that all efforts seemed futile. At the close of the experiment there was scarcely a fish in the group which was not infested. It was also noticed, while handling the fish, that the fish of this group felt soft and flabby as compared to the others.

TABLE 2 Catfish

Diet	Number survived	Av. initial length as mm.	March 17-May 4 Av. gain as mm.	March 17-May 4 % gain	March 10-July 6 Av. gain as mm.	March 10-July 6 % gain
1. −G −B	45	49.88	1.6	3.21		
2. −B	48	49.46	1.29	2.61		
3. +B +G control	36	49.50	1.83	3.70		
4. Buttermilk	48	48.84	0.45	0.92		
5. Meat	47	49.76	1.6	3.21	5.99	12.05
6. −D	38	49.4	−0.66	−1.33	0.02	0.04
7. +D control	21	49.65	0.42	0.85	2.58	5.2

Examination of Table 2 and Fig. II shows again that vitamin D is necessary for the growth of the fish studied. Concerning the vitamins B and G, neither the rate of growth nor the appearance or survival of the fish give any indication that their absence from the diet is detrimental. The high mortality in the control group (Diet 7) at the end of the third week was due to an accidental overdose of potassium permanganate, which was being used to keep down fungus. Thereafter, salt, (5 parts N_aC_1 to 1 part M_gSO_4) was used in the concentration of 1 kilo to 40 gal. of water, with no apparent detrimental effects, and the use of permanganate was abandoned.

In analyzing the data for the first seven weeks, March 17 to May 4, it is probable no significance should be attached to the decidedly inferior growth made by the fishes on diet 4. These fishes averaged considerably smaller than the other groups and it appeared throughout that the smaller cat fish were more affected by handling and other experimental conditions than were the larger ones. It also appears in Fig. II, that the low average gain of this group was due to an actual decrease in size during the first three weeks after their transfer from the Pratt Hatchery, but that, at the time the experiment closed, they were making progress comparable to that of fishes on the other diets.

As in the case of the goldfish, the diets 6 and 7 are not strictly comparable to diets 1 to 5, since a different cereal was used. A comparison of diets 6 and 7, however, shows a decided advantage for those having vitamin D. During the last nine weeks of the experiment, May 4 to July 6, diets 5, 6 and 7 are comparable, since

oatmeal was substituted for rice in diet 5 at the beginning of this period. Examination of Fig. II for this period shows that, with the onset of warm weather about the middle of June, the fishes on the control diets began a period of rapid growth, whereas the group lacking Vitamin D began to decline rapidly. By the close of the experiment these fishes showed a decided loss of appetite, whereas the control fishes ate ravenously.

In order to determine whether a noticeable difference in skeletal development, such as would be expected in case of rickets, could be detected between the plus and minus vitamin D groups, ten fishes from the minus D group were selected and compared with ten fishes from the plus D group of the same size. In each case the difference in weight between the two fish so selected was within 0.05 gms. Each fish was placed in a test tube containing 20 cc. of 2.5 per cent commercial pepsin in 0.4 per cent HC_1, and subjected to digestion at 37 degrees centigrade for three days. At the end of that time the products of digestion were decanted off and the skeletal parts washed and examined. In each case the bones of the plus vitamin D fishes were noticeably larger, less fragile, and more rigidly connected, than those of the minus vitamin D fishes of the same weight. Thus the absence of vitamin D from the diet of these fishes not only checked their growth, but also produced poor skeletal development comparable to rickets in higher animals.

In comparing the plus vitamin D group with the meat fed group we find a decided difference in favor of the latter. Not only did the fishes whose diet contained meat make better growth in length, but their superior appearance, better color, and plumper condition were so marked as to be readily noted, even by those unacquainted with our experiments who chanced to come into the laboratory. They also seemed less susceptible to fungus and tail rot. Whether this superiority of the meat containing diet can be accounted for by the higher protein content, or by the factor H of Dilley and Bing, or by some unidentified constituent, has not been determined.

A comparison between the goldfish and cat fish shows that both require vitamin D. There are some indications that goldfish also require vitamin G. In the case of the cat fish there are no such indications, although the experiments were of too short duration to be in any way conclusive. The addition of meat to what, for mammals, would be an adequate synthetic diet, produces a marked improvement in growth in the case of the cat fish, whereas no such marked effect is noted in case of the goldfish. Although further experiments should be pursued through a longer period of time before considering such a difference between the food requirements of the two species as established, yet such a difference would not be at all surprising. The food habits of the goldfish are largely vegetarian, whereas the cat fish is largely carnivorous. Corres-

pondingly vitamin G is found primarily in plants, which are eaten by the goldfish to a much greater extent than by catfish.

SUMMARY

Experiments involving 700 goldfish and 350 young channel cat fish indicate that vitamin D is essential in the diets of both forms. In the case of the channel cat, its absence has been shown to result in the inferior skeletal development characteristic of rickets.

The growth producing food factor, vitamin G, also appears to be necessary to the health and development of goldfish, although the experiments furnished no evidence that it is required by the cat fish.

In the case of cat fish, the addition of raw meat to a theoretically adequate synthetic diet resulted in a 130 per cent increase in growth.

This investigation was undertaken as a joint project of the Kansas State Department of Fish and Game, and the Kansas State College. The authors are indebted to Dr. R. N. Waller of Manhattan, Kansas, for the X-rays used in the vitamin D experiments, to the Anheuser-Busch Company of St. Louis for furnishing fresh brewer's yeast at regular intervals, and to Dr. L. O. Nolf and Mrs. W. W. Crawford for suggestions in the preparation of the diets.

LITERATURE CITED

Committee, Amer. Coc. Biol. Chem.
1929. Vitamin B terminology. Science, 69: 274-276.

Davis, H. S. and M. C. James
1924. Some experiments on the addition of vitamins to trout foods. Trans. Amer. Fish. Soc., 54: 77-111.
1925. Some experiments in trout feeding. Trans. Amer. Fish. Soc., 55: 115-118.

Davis, H. S.
1927. Some results of feeding experiments with trout fingerlings. Trans. Amer. Fish. Soc., 57: 281-287.

Goldberger, J. and W. F. Tanner
1925. A study of the pellagra preventive action of dried beans, casein, dried milk, and brewer's yeast with a consideration of the essential preventive factors involved. U. S. Public Health Report, 40: 54.

Goldberger, J., O. A. Wheeler, R. D. Lillie, and L. M. Rogers.
1926. A further study of butter, fresh beef, and yeast as pellagra preventives, with consideration of the relation of factors P-P of pellagra to vitamin B. U. S. Public Health Report, 41: 297.

Hogan, A. G., N. B. Guerrant, and H. L. Kempster.
1925. Concerning the adequacy of synthetic diets for growth of the chick. Jour. Biol. Chem., 64: 113-124.

Layfberger, V.
1926. Physiological Abstracts, 11: 221.

McCay, C. M., F. C. Bing, and W. E. Dilley.
1927. The effect of variations in vitamins, protein, fat, and mineral matter in the diet upon the growth and mortality of eastern brook trout. Trans. Amer. Fish. Soc., 57: 240-249.

McCay, C. M., and W. E. Dilley.
1927. Factor H in the nutrition of trout. Trans. Amer. Fish. Soc., 57: 250-260.
Richet, C., Ozner, and Richard.
1925. Jour. Compt. Rend., 181-637.
Sherman, H. C., and A. Spehn.
1925. A critical investigation on the application of the rat growth method of study of vitamin B. Jour. Amer. Chem. Soc., 25: 2719-2728.
Thompson, D. H.
1928. The "Knothead" carp of the Illinois River. Bull. Ill. State Lab. of Nat. Hist., 18: 285-320.

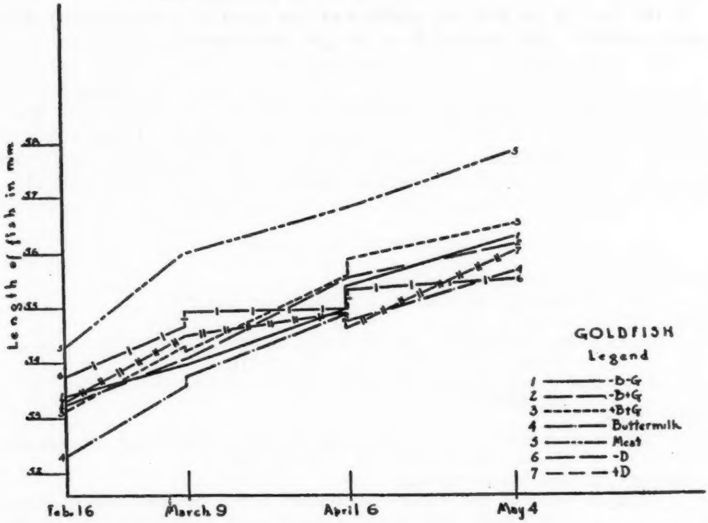

Fig. I. Graph showing the average growth in length of goldfish upon the experimental diets studied. Abrupt vertical breaks in lines indicate apparent increases or decreases in length due to death of the smaller or larger fish, and are not due to growth.

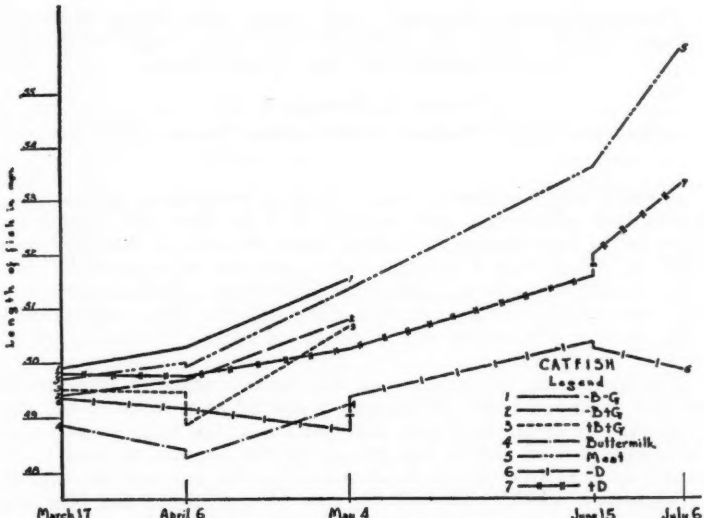

Fig. II. Graph showing the average growth in length of channel cat fingerlings upon the experimental diets studied. Abrupt vertical breaks in lines indicate apparent increases or decreases in length due to death of the smaller or larger fish, and are not due to growth.

Fig. III. Meat scraps caused a failure in growth and a mortality when no fresh meat was added, contrast curves 13 and 14. Liver treated with calcium hypochlorite revived the fish, curve 14A. Buttermilk caused a failure in growth and a mortality when fed exclusively, curve 15. Vacuum dried liver revived the fish in this case, curve 15A.

PRELIMINARY REPORT ON THE GROWTH RATE, DOMINANCE, AND MATURITY OF THE PIKE-PERCHES *(STIZOSTEDION)* OF LAKE ERIE*

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A racial and life-history study of the pike-perches (yellow pike-perch, blue pike-perch, and sauger) of Lake Erie has occupied a place in the program of the United States Bureau of Fisheries since 1927, at which time a comprehensive program of commercial fisheries investigations was initiated on Lake Erie. Only a portion of the vast amount of data collected since 1927 has been studied critically, so that this report will be restricted largely to the collections of 1927 and 1928.

The systematic relationships of the three species of pike-perches are not discussed here. The paper is limited to a study of the rate of growth as determined by a study of the scales, to a discussion of the dominance of certain age-groups in the population, and to an examination of frequency tabulations of data on sex and immaturity.

Adamstone (1922)[1] studied the rate of growth of the blue and yellow pike-perches of the Canadian waters of Lake Erie. His conclusions were as follows: The rate of growth of the yellow pike-perch is fairly uniform, showing only a small decline for the later years of life studied. The decline in growth rate is accompanied by an acceleration of the rate of increase in weight. In the blue pike-perch there is a slight decrease in rate of growth during the second year of life, and a very marked decrease in rate of growth begins at about the fifth year. There is no compensation for decrease in length-increment by a more rapid increase in weight as occurs in the yellow pike-perch. The blue pike-perch do not reach so great a size as the yellow pike-perch. Adamstone determined ages by examining the scales with a microscope and made no scale measurements or increment calculations. His general results do not differ greatly from those obtained by the author, although the number of fish employed by Adamstone for the study (50 blue pike-perch and 25 yellow pike-perch) would seem to have been far too small to yield conclusive results.

DISTRIBUTION OF THE PIKE-PERCHES IN LAKE ERIE

Three species of *Stizostedion* are recognized in Lake Erie: the sauger, or sand-pike, *S. canadense* (Smith); the yellow pike-perch (also commonly called yellow pickerel, wall-eyed pike, hard pike, and

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[1]Adamstone, F. B., 1922. Rates of growth of the blue and yellow pike-perch (*Stizostedion vitreum*) in Lake Erie. University of Toronto Studies, No. 20. Publication of the Ontario Fisheries Research Laboratory No. 5, pp. 75-86. Tables 5 text figures. Toronto.

doré in commerce), *S. vitreum* (Mitchill); and the blue pike-perch, *S. glaucum* Hubbs.

The yellow pike-perch are most concentrated in the western or more shallow portion of Lake Erie, in the region west of a line drawn from the mouth of Sandusky Bay to Point Pelee, the larger individuals being most abundant in the region west of the islands. East of that line the yellow pike-perch are much less abundant and inhabit chiefly the waters near the shore. Very infrequently, however, is it encountered in appreciable numbers in waters more than eight fathoms deep.

The blue pike-perch, which at present is regarded as specifically distinct from the yellow, seems to be a deeper water form than the yellow. Almost all the catches of this species occur east of the line defined above, in the central area of the lake. Considering the American waters of Lake Erie the region of greatest abundance extends from Cleveland, Ohio, to Erie, Pennsylvania, with the center of abundance probably off Ashtabula, Ohio. It is safe to say that blue pike-perch except for a small percentage are not taken to any great extent in waters less than six fathoms in depth except during the spawning season, when they are taken in shallow water inshore.

The sauger, the third species under consideration, is most abundant in the region of the islands in the western part of the lake. It is taken there in large numbers in the spring both by commercial trap-nets and by gillnet tugs which frequently make long runs in order to fish in this rather limited area. As a rule fewer saugers are caught during the remainder of the commercial fishing season, although heavy fall catches have sometimes been made off Sandusky, Ohio, and in Michigan waters. A few stragglers occur in shallow water to the eastward as far as Dunkirk, New York.

Materials

The material upon which part of this paper is based consists of scale collections from unassorted samples of the catch taken in commercial nets. Ages have been determined and increments calculated from measurements of the scales of 1430 yellow pike-perch, 1275 blue pike perch and 905 saugers.

The 1927 collections were made in the vicinities of Sandusky and Vermilion, Ohio. The 1928 material was secured from the following ports: Port Clinton, Sandusky, Vermilion, Lorain, and Conneaut, Ohio; Erie, Pennsylvania; and Dunkirk, New York. For the determination of size at sexual maturity, scale collections and measurements made in 1929 at all of the ports mentioned above, and in the spring of 1932 at Port Clinton and Toledo, Ohio, have been added to the 1927 and 1928 material. The bulk of the material of all three species which was used for age and growth studies was taken in the fall, after October first. Some blue pike-perch and saugers taken in

the summer were incorporated, since comparison of data by months showed no significant differences.

All of the 1927 and 1928 material was secured from commercial trapnets and pound-nets except 195 blue pike-perch which were taken in commercial gillnets in the vicinity of Dunkirk, New York. It was necessary to use the gillnet collections from Dunkirk since no trapnets or pound-nets are operated in this locality. The frequency distribution of the Dunkirk blue pike-perch material is not essentially different from that secured elsewhere in Lake Erie and any differences probably have disappeared during the process of inclusion in the general averages for the lake. Generally speaking, trapnets and pound-nets afford a much better sample of the population than do gillnets, which have an upper as well as a lower limit of selectivity.

Methods

The method used for age and growth-rate studies from scales is known as the "scale method," the best recent discussions of which are given by Creaser (1926)[2] and Van Oosten (1923[3] and 1929[4]). Since the age-markings in the Lake Erie pike-perches seem to be very distinct, it has been assumed that they actually represent winter annuli.

The age of the fish was determined by counting the number of annual rings (annuli) and considering the growth outside the last annulus to be that of the last year of life. Ages were designated by Roman numerals as follows: a fish having no annuli on its scales is in its first year of life and is designated "0"; a fish whose scales show a single annulus is in its second year of life and is designated as "I"; and similarly for the later years of life.

Scales magnified about 19 diameters were measured in millimeters from the focus of the scale, along the anterior radius, to each of the annuli and to the margin of the scale. The theoretical standard length at the end of each year of life was determined by the formula $X_n=(A_n.L)/S$, where X_n is the unknown standard length of the fish at the end of the year n; A, the length of the anterior radius of the scale at the end of the year n (distance between focus of the scale and annulus n); L, the standard length of the fish in millimeters at the time of capture; and S, the distance from the focus to the margin of the scale. No corrections were made in calculated lengths to compensate for late formation of the scale and for the probable

[2]Creaser, Charles W., 1926. The structure and growth of the scales of fishes in relation to the interpretation of their life history, with special reference to the sunfish *Eupomotis gibbosus*. University of Michigan, Museum of Zoology, Miscellaneous publications No. 17, Ann Arbor.

[3]Van Oosten, John, 1923. A study of the scales of whitefish of known ages. Zoologica, Vol. 2, No. 17, Papers of the New York Aquarium, No. 9, pp. 380-412.

[4]Van Oosten, John, 1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bulletin of the Bureau of Fisheries, Vol. 44, 1928 (1929), pp. 265-428. 46 text figs. 64 tables, Washington.

unequal growth of scale length and body length during early years of life. At the present time the nature and extent of this correction is not known, hence for purposes of this paper it has been assumed that the relationship between growth of scale and growth of body in length are in simple and direct proportion.

Age, Growth, and Dominance of Yellow Pike-Perch

The following discussions of calculated lengths at the end of the various years of life, and annual increments of the pike-perches are presented with the realization that material for the older age-groups is not always adequate although the samples were representative of the catch. This means therefore that older fish were relatively few in the catch of the commercial nets from which the scale samples were secured. As mentioned in the section headed "Materials," the bulk of the collections were made in the fall. Since averages for various localities showed no significant differences, the materials from all localities and all dates have been grouped together in Tables 1, 2, 3, and 4.

As will be seen later in the discussion of sexual maturity, the females appear to attain sexual maturity later, or at a larger average size than the males. The possibility of sexual dimorphism in growth is recognized but the 1927 and 1928 collections provided no usable sexed scale material and hence a comparison of the growth by sexes is impossible. Materials collected in 1929, 1930, and 1932 which are being studied at the present time and which are not considered in the age and growth-rate studies in the present report will provide for such a comparison in a future publication.

The number of fish of each age-group collected in 1927 and 1928 and used in study of age and growth-rate is shown in Table 1. No yellow pike-perch of the 0 age-group were taken in either year, due to the fact that they were probably too small to be retained by the commercial gear. Fish of age-group I (349 in number) were most numerous in the collections of yellow pike-perch in 1927 and fish of age-group II (803) were most numerous in 1928. The dominance of these age-groups in 1927 and 1928, which are of the same year-class, points to an unusually large or successful hatch of yellow pike-perch in the spring of 1926. Relatively few fish were taken of the older age-groups in either year.

The average calculated lengths and increments for the 1430 yellow pike-perch collected in 1927 and 1928 and used in the age and growth-rate study are shown in Table 2. The combined average annual increments of this table (see also Figure 1) show that the growth in the first year of life was 91 millimeters, in the second 92 millimeters, in the third 65 millimeters, and in the fourth 79 millimeters. Following the fourth year of life there appears to have been a progressive decrease in annual increment, although the average values for these cannot be considered very accurate.

Age, Growth, and Dominance of Blue Pike-Perch

The scales of 1275 blue pike-perch were collected in 1927 and 1928. No fish of the 0 age-group were taken in either year and in 1928 no fish of age-group I were taken. A large percentage of the fish taken in 1927 (253) were of age group I and the majority of the 1928 fish were of age-group II (378). (See Table 1.) This indicates the presence of a dominant year-class which points to a probable large or successful hatch of blue pike-perch in the spring of 1926. The 1924 year-class was represented by 361 individuals in age-group III in 1927. However, only 69 blue pike-perch of age-group IV were taken in 1928. The fact that the same relative abundance indicated by age-group III in 1927 was not shown by age-group IV in 1928 probably points to a very intense fishing for blue pike-perch in Lake Erie. Most of the individuals of age-group IV are just above the legal size-limit of 11 inches total length in Ohio. The absence of individuals of age-groups V and VI in 1928 supports the contention that this species is subjected to intense fishing.

The average calculated lengths and increments for the 1275 blue pike-perch taken in 1927 and 1928 are shown in Table 3. The combined average annual increments (increment curve shown in Figure 1) indicate that a growth of 67 millimeters occurred during the first year of life, 80 millimeters during the second, 59 during the third, 38 during the fourth, and 37 millimeters during the fifth year of life. Since only one fish of age-group V was taken in the collections, it is probable that an average based on a more representative number of individuals would show a greater decline in growth rate after the fourth year of life.

Age, Growth, and Dominance of the Sauger

In 1927 (Table 1) the best represented age-groups in the sauger collections were II and III and the same age-groups likewise included the best representation in 1928. Age-group II in 1928 may indicate a dominant year-class which was prevented from showing up in age-group I in 1927 because of the selectivity of the commercial nets which allowed a large percentage of the individuals of age-group I to escape. Age-group III, which was represented by 157 individuals in 1927, probably did not survive in sufficient numbers in 1928 to show the same relative abundance of age-group IV in the latter year, due presumably to the intensive drain of the commercial fishery.

Table 4 shows average calculated lengths and increments for the 905 saugers collected in 1927 and 1928 and used for age and growth-rate studies. Saugers in Lake Erie showed an average growth of 85 millimeters during the first year of life, 88 during the second, 56 during the third, 39 during the fourth, 31 during the fifth and 47 during the sixth year of life. The growth of 47 millimeters indi-

cated for the fifth year of life may not represent the average increment for age-group VI since only five individuals of age-group VI were contained in the collections.

Comparison of the Growth of the Three Species

The growth curves and annual increment curves for yellow pike-perch, blue pike-perch, and saugers are shown in Figure 1. The yellow pike-perch is the fastest growing of the three species, the blue pike-perch is the slowest growing, while the sauger grows at a rate intermediate between that of the yellow and blue pike-perches. The growth curve of the yellow pike-perch closely approximates a straight line. The increment curve shows a slight (and perhaps not significant) increase in rate during the second year of life followed by a decrease of small magnitude in later years. Data for later years, beyond those for which data are presented here, may show a more rapid decrease in growth-rate. The fact that the growth of the third year of life in the yellow pike-perch was less than that of the fourth year probably does not represent an average condition, and may have been caused by the influence of an unfavorable growth season of a single year-class.

The growth curves of the blue pike-perch and the sauger are of the same type and show a rapid growth during the first year of life, an increase in growth-rate during the second year of life, followed by a progressive decline in growth-rate during the later years of life. Any significant difference in growth rate between the blue pike-perch and the sauger, as shown by the data, occurred during the first two years of life, in which the sauger grew more rapidly than the blue pike-perch. There was very little difference in growth-rate between blue pike-perch and saugers following the third year of life, although the decrease in growth-rate of the sauger appears to be slightly greater than the decrease of the blue pike-perch.

The legal size-limit for yellow pike-perch in Ohio and Pennsylvania is 13 inches total length, equivalent to 279 millimeters standard length. In New York the size limit is 12 inches total length. The size limit for blue pike-perch and saugers on Lake Erie is 11 inches total length, equivalent to 235 millimeters standard length. On the basis of the data presented in Figure 1 it is seen that all three species attain legal size some time after the formation of the third annulus, and before the formation of the fourth annulus, or in other words, during the fourth year of life. It was mentioned in an earlier part of the paper that there may be a sex difference in growth-rate in the pike-perches which the material considered here does not provide the means of investigating. Consideration of sexual dimorphism in growth-rate must be left for a future publication.

Relationship of Length and Sexual Maturity

The percentage of immaturity of males and females in the pike-perch populations in relation to the legal size limits operative on Lake Erie is a question of great practical importance to the fisheries. In Tables 5, 6, and 7 are presented the number of fish examined and the number and percentage of immature individuals by frequency-groups of half inches total length for each of the three species. Frequency groups are arranged, in general, as follows: 9½ to (but not including) 10 inches, 10 to (but not including) 10½ inches, etc. All fish for which sex and maturity were obtained have been grouped together irrespective of the time of year when caught. These tables are not, therefore, representative of any particular season of the year but present a probable average picture of conditions throughout the year. Certain difficulties in sex determination of immature individuals made designation as male and female uncertain during the early period of collecting. Therefore, in many samples, fish were recorded as mature or immature without any specific designation of sex. For this reason the total number of individuals considered in each of the three tables is greater than the combined total of males and females.

1. Yellow Pike-Perch

The data for yellow pike-perch are shown in Table 5. In the tabulation of all fish of both sexes combined (columns 2, 3, and 4) it is seen that all fish less than 11 inches in total length were immature. The most significant drop in percentage of immaturity occurred between the frequency-groups 13 to 13½ inches and 13½ to 14 inches, where the percentage decreased from 35.71 to 11.21. On the basis of the data for all fish combined it may be stated that virtually all Lake Erie yellow pike-perch 14½ inches in total length and larger are sexually mature.

All male yellow pike-perch less than 11 inches in total length were immature. The big drop in percentage occurred between frequency-groups 12½ to 13 and 13 to 13½ inches. Virtually all males of 13½ inches total length and larger were mature fish.

All female yellow pike-perch less than 12 inches in total length were sexually immature; in fact, it may be stated that virtually all females less than 12½ inches total length were immature. The significant drop in percentage occurred in the frequency-group 14 to 14½ inches, which contained 7.69 per cent of immature individuals. Virtually all females 15 inches in total length and larger were sexually mature.

On the basis of Table 5 it appears that the present legal size-limit of 13 inches on Lake Erie may afford adequate protection to the males of the yellow pike-perch, but if the females are to be allowed to spawn at least only once it appears that the present size-limit is

too low and should be increased to at least 15 inches total length for all yellow pike-perch.

In the determination of maturity and immaturity the fish were called mature if there was evidence of early formation of sex products, so that a fish often was called mature even though it may never have spawned. Such fish were called mature because the development of the sex organs indicated that they would spawn during the next spawning season. Many of the fish contained in spring collections which were called mature and in which the sex products were ripe or nearly ripe likewise may never have spawned but would have done so had they not been taken by the nets before the completion of the actual act of spawning. Therefore the suggested size-limits based on percentages of maturity may not be high enough to allow all fish to spawn at least once, although the figures may indicate virtually complete maturity at that size.

No adequate biological information exists to indicate the number of times any freshwater fish should spawn on the average in order to maintain the population so that it will not be depleted by the commercial fishery. A size-limit which allows all fish surviving their natural enemies to spawn once *may* preserve the population, but it is conceivable that two, or even more, spawnings may be necessary. Although the male pike-perches mature at a smaller size than the females, size-limits must be governed by the size at maturity of females. The size-limits given in this paper are suggested as absolute minima. The fact that such a large percentage of the catch of commercial nets is just above the legal size-limit is a warning which should not pass unheeded.

2. Blue Pike-Perch

Blue pike-perch reach maturity at a smaller average size than do yellow pike-perch. The percentage of immaturity in various size-groups is shown in Table 6. Some mature individuals occur in all size-groups considered (9½ inches and above, total length). Considering all fish of both sexes together, a significant drop in the percentage of immaturity first occurs in the frequency-group, 13 to 13½ inches total length. In this frequency-group the percentage was only 9.09. Virtually all blue pike-perch 13½ inches and larger were mature fish.

Virtually all male blue pike-perch were mature at 11½ inches total length and in the frequency-group 11 to 11½ inches, the percentage of immaturity was only 10.34.

The females mature at a larger size than do the males, virtually all being immature at a total length less than 11 inches. There is no significant drop in percentage of immaturity until the frequency-group 13 to 13½ inches is reached. Even this group contained 17.39 per cent of immature females. Virtually all females larger than 13½ inches were mature.

As in the case of the yellow pike-perch, the existing size limit for blue pike-perch on Lake Erie (11 inches total length) appears to afford more or less adequate protection to the males, but from the data at hand it appears that females should be protected up to at least 13½ inches in order to help insure that they may spawn at least once.

3. Saugers

Saugers reach maturity at a smaller size than either the yellow or the blue pike-perches. Table 7 shows the percentage of immaturity of the sauger according to frequency-groups of total length. Considering all fish, irrespective of sex, the significant drop may be considered as occurring in the frequency-group 11 to 11½ inches, which contained 13.04 per cent of immature individuals, while the next higher group, 11½ to 12 inches, contained 11.64 per cent immature individuals. At 13 inches virtually all saugers were mature.

Male saugers apparently mature at a very small size. Only 9.21 per cent of the males in the lowest frequency-group studied (9½ to 10 inches total length) were immature. At 10½ inches virtually all males were mature.

The females mature later in life than the males. Virtually all females less than 10½ inches in total length were immature. In the frequency-group 10½ to 11 inches, 63.64 per cent of the females were immature, at 11 to 11½ inches 28.57 per cent were immature, and at 11½ to 12 inches 16.87 per cent were still immature. The significant drop in percentage of immaturity in the female saugers occurs at 12 to 12½ inches, in which frequency-group the percentage of immaturity was 9.84. All female saugers were mature at 13 inches total length.

The legal size-limit of 11 inches for saugers in Lake Erie presumably gives ample protection to the males but appears to be too low to afford adequate protection to spawning females. It is recommended that the limit be increased to at least 12½ inches, at which size probably all but about 10 per cent of the females have spawned or will soon spawn.

Acknowledgments

The assistance, criticisms and advice of Dr. John Van Oosten, In Charge Great Lakes Fishery Investigations for the United States Bureau of Fisheries, have been most valuable and are gratefully acknowledged. To Dr. Carl L. Hubbs, Curator of Fishes in the Museum of Zoology, University of Michigan, thanks are due for many helpful suggestions.

Summary

The paper is a preliminary report on the age, growth-rate, and dominance of the pike-perches of Lake Erie (yellow pike-perch, blue pike-perch, and sauger) as determined from examination and measurement of their scales, and on the size at sexual maturity.

The general distribution of the pike-perches in Lake Erie is as follows: Yellow pike-perch are most abundant west of a line drawn from the mouth of Sandusky Bay to Point Pelee and confined to waters less than 8 fathoms in depth. Blue pike-perch are most abundant east of the line defined above; in American waters the center of abundance is probably off Ashtabula, Ohio, and are seldom taken in less than six fathoms of water except during the spawning season. The distribution of the sauger is approximately the same as that of the yellow pike-perch.

Dominant age-groups were observed in the pike-perch collections of 1927 and 1928. The 1926 year-class of yellow pike-perch and blue pike-perch as represented by age-group I in 1927 and age-group II in 1928 was dominant. The 1926 year-class was probably dominant also in the sauger collections, since a large percentage of the fish collected in 1928 were of age-group II. Dominance was not shown by age-group I of the saugers collected in 1927, presumably due to the selective action of the commercial nets.

The yellow pike-perch grows most rapidly and shows no significant decrease in growth-rate up to the end of the fifth year of life. Saugers grow more slowly than yellow pike-perch and show a rapid decrease in growth-rate following the second year of life. The blue pike-perch is the slowest growing of the three species, but the average decrease in growth rate is less than in the sauger following the third year of life.

The sauger matures at a smaller size in both sexes than the blue pike-perch, and the blue pike-perch matures at a smaller size than do the yellow pike-perch.

A study of the relationship of percentage of immaturity to the existing legal size-limits now in force in Lake Erie indicates that the present size limits should all be increased to afford better protection to spawning females. In order to help insure spawning by females once, a size-limit of 15 inches total length is indicated as a minimum for yellow pike-perch. That size-limit is recommended as the minimum for adoption. On a similar basis, a minimum of 13½ inches total length is recommended for blue pike-perch, and a minimum of 12½ inches total length for saugers.

TABLE 1

Number of yellow pike-perch, blue pike-perch, and saugers of each age-group collected in 1927 and 1928. Dominance of certain year-classes is indicated.

Year of collection	Age Groups 0	I	II	III	IV	V	VI
				Yellow Pike-perch			
1927	0	349	50	7	0	0	0
1928	0	144	803	53	19	4	1
				Blue Pike-perch			
1927	0	253	72	361	57	0	0
1928	0	0	378	84	69	1	0
				Saugers			
1927	0	68	174	157	56	17	5
1928	0	11	299	116	2	0	0

TABLE 2

Yellow pike-perch, Lake Erie, 1927 and 1928. Number of fish, average actual and calculated lengths and annual increments for fish of age-groups I, II, III, IV, V, and VI

Age group	No. of fish	Actual length	Calculated length at end of growth years: 1	2	3	4	5	6
I	493	216	101	—	—	—	—	—
II	853	259	86	184	—	—	—	—
III	60	297	85	170	240	—	—	—
IV	19[1]	355	90	187	263	322	—	—
V	4[1]	414	110	204	280	344	391	—
VI	1[1]	475	129	220	292	349	414	458
Average (1430 fish)			91	183	248	327	396	458
Annual increment			91	92	65	79	69	62

[1]1928. None taken in 1927.

TABLE 3

Blue pike-perch, Lake Erie, 1927 and 1928. Number of fish, average actual and calculated lengths and annual increments for fish of age-groups I, II, III, IV, and V

Age group	No. of fish	Actual length	Calculated length at end of growth years: 1	2	3	4	5
I	253[1]	170	80	—	—	—	—
II	450	217	70	156	—	—	—
III	445	248	58	140	208	—	—
IV	126	272	63	141	201	244	—
V	1[2]	330	74	135	186	239	281
Average (1275 fish)			67	147	206	244	281
Annual increment			67	80	59	38	37

[1]1927. None taken in 1928.
[2]1928. None taken in 1927.

TABLE 4

Saugers, Lake Erie, 1927 and 1928. Number of fish, average actual and calculated lengths and annual increments for fish of age-groups I, II, III, IV, V, and VI

Age group	No. of fish	Actual length	Calculated length at end of growth years: 1	2	3	4	5	6
I	79	181	103	—	—	—	—	—
II	473	249	88	182	—	—	—	—
III	273	279	75	165	234	—	—	—
IV	58	302	78	150	216	272	—	—
V	17[1]	318	86	159	209	258	297	—
VI	5[1]	351	92	152	207	254	305	346
Average (905 fish)			85	173	229	268	299	346
Annual increment			85	88	56	39	31	47

[1]1927. None taken in 1928.

TABLE 5

Yellow pike-perch, Lake Erie. Number of fish and number and percentage of immature individuals of each sex and of both sexes combined. Fish grouped according to total length in inches

Size Group	All Fish Total	No. immature	% immature	Males Total	No. immature	% immature	Females Total	No. immature	% immature
9½ to 10 inches	267	267	100.00	28	28	100.00	29	29	100.00
10 to 10½ inches	214	214	100.00	20	20	100.00	22	22	100.00
10½ to 11 inches	173	173	100.00	25	25	100.00	32	32	100.00
11 to 11½ inches	107	97	90.65	22	17	77.27	24	24	100.00
11½ to 12 inches	102	91	89.22	33	24	72.73	20	20	100.00
12 to 12½ inches	102	86	84.31	30	16	53.33	24	23	95.83
12½ to 13 inches	98	46	46.94	66	19	28.79	30	17	56.67
13 to 13½ inches	112	30	35.71	81	5	6.17	18	8	44.44
13½ to 14 inches	116	13	11.21	99	1	1.01	10	6	60.00
14 to 14½ inches	129	16	12.40	110	0	0.00	13	1	7.69
14½ to 15 inches	183	5	2.23	151	0	0.00	20	1	5.00
15 inches and over	384	5	1.30	164	0	0.00	218	5	2.29

TABLE 6

Blue pike-perch, Lake Erie. Number of fish and number and percentage of immature individuals of each sex and of both sexes combined. Fish grouped according to total length in inches

	All Fish			Males			Females		
Size Group	Total	No. immature	% immature	Total	No. immature	% immature	Total	No. immature	% immature
9½ to 10 inches	439	391	89.07	175	140	80.00	211	211	100.00
10 to 10½ inches	680	538	79.12	268	167	45.38	306	303	99.35
10½ to 11 inches	478	322	67.36	172	66	38.37	207	195	94.20
11 to 11½ inches	350	120	37.14	145	15	10.33	129	79	61.24
11½ to 12 inches	285	86	30.18	100	2	2.00	100	51	51.00
12 to 12½ inches	298	101	33.89	78	1	1.28	141	83	58.86
12½ to 13 inches	106	31	29.25	19	0	0.00	59	24	40.68
13 to 13½ inches	66	6	9.09	18	0	0.00	23	4	17.39
13½ in. and over	73	1	1.37	21	0	0.00	26	1	3.85

TABLE 7

Saugers, Lake Erie. Number of fish and number and percentage of immature individuals of each sex and of both sexes combined. Fish grouped according to total length in inches

	All Fish			Males			Females		
Size Group	Total	No. immature	% immature	Total	No. immature	% immature	Total	No. immature	% immature
9½ to 10 inches	138	62	44.93	76	7	9.21	35	35	100.00
10 to 10½ inches	175	62	35.43	94	4	4.26	34	32	94.12
10½ to 11 inches	195	45	23.08	113	1	0.88	44	28	63.64
11 to 11½ inches	322	42	13.04	200	1	0.50	77	22	28.57
11½ to 12 inches	275	32	11.64	137	0	0.00	83	14	16.87
12 to 12½ inches	154	11	7.40	71	0	0.00	61	6	9.84
12½ to 13 inches	147	6	4.08	58	0	0.00	78	4	5.13
13 to 13½ inches	110	2	1.82	48	0	0.00	58	0	0.00
13½ to 14 inches	93	1	1.08	11	0	0.00	75	0	0.00
14 inches and over	37	0	0.00	2	0	0.00	28	0	0.00

Discussion

MR. TUNISON: Can Mr. Deason say anything with regard to the possibility of sterility in these large fish?

MR. DEASON: We have no absolute evidence of sterility, but public opinion of course is that the extremely large individuals may be sterile. What you are getting at, I suppose, is that some of the older individuals may have been sterile?

MR. TUNISON: Yes.

MR. DEASON: That is quite possible. We have known occasional individuals which were well beyond the average size of maturity to have been sterile, but I think they were fortuitous in occurrence.

MR. TUNISON: Can Mr. Hayford say anything in regard to the probability of sterility in large trout? Does he occasionally find sterility in the breeders?

MR. HAYFORD: Not so much now, in the work we have done on the trout, and the trout are the only fish we have worked on.

MR. TUNISON: I suppose your practice would be, by selective breeding, to get rid of those that had very few eggs?

MR. HAYFORD: Yes.

MR. TUNISON: Do you occasionally find a large trout that produces no eggs?

MR. HAYFORD: That very seldom happens with us; in fact I do not know that we have found any. We have been running that work since 1921. We take about 200 pairs, put the eggs from each pair in a separate compartment, and then throw out everything that does not score 90 or better.

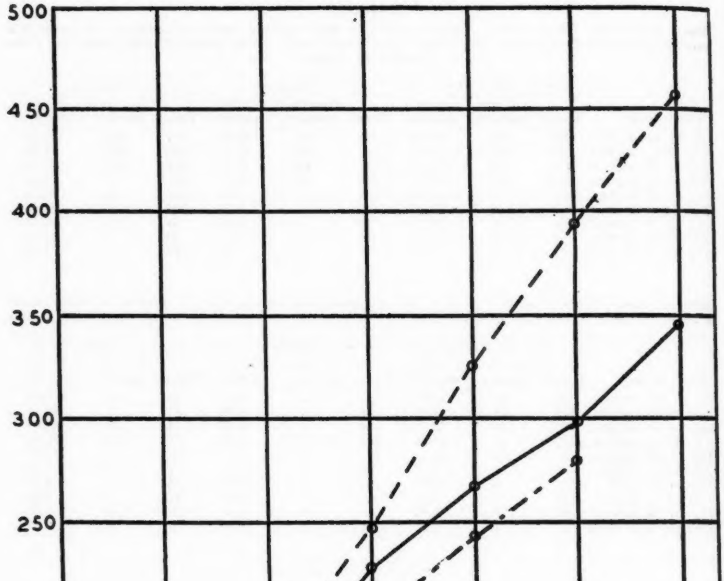

FIGURE 1.—Growth curves and annual increment curves for yellow pike-perch, blue pike-perch, and saugers, Lake Erie, 1927 and 1928 (combined). Size calculated to length at end of previous winter. (Yellow pike-perch — — —; sauger ———; blue pike-perch – · – · – ·)

MILLIMETERS (STANDARD LENGTH)
YEARS (indicated by number of winters lived)

THE GROWTH RATE OF RAINBOW TROUT FROM SOME MICHIGAN WATERS

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Ages of 329 rainbow trout from Michigan streams and lakes were determined by study of the scales. All but twenty-two specimens were from streams of western Michigan (Lake, Manistee and Newaygo counties). The fish ranged in size from 1.75 to 31.0 inches (total length) and represented both adult stages (97 individuals) and immature stages (232 individuals). By means of seining, angling, and trapping of fish ascending to spawn, some individuals of every age group up to seven winters were obtained. The material was collected during 1928 (1 specimen), 1930 (200 specimens), 1931 (116 specimens), and 1932 (12 specimens) and includes fish taken in April, May, June, July and August. The largest series of scales of adult fish from any one locality was obtained from wild-trapped fish held at the Manistee spawn-taking station of the State Department of Conservation. Measurements and scales were taken from sixty-six fish, representative of size ranges in a much larger number, without apparent injury to the fish. The material studied included scale samples obtained through cooperation of anglers, Department of Conservation field men, and the U. S. Bureau of Fisheries.

Scales were mounted in glycerine jelly and were studied with a projection microscope having a ground-glass screen. Measurements of anterior field (from focus of scale out toward the margin) were taken for use in computing fish lengths at various years of life.

Migratory and Non-Migratory Rainbows

Field work on Michigan trout streams has clearly indicated that some rainbow trout remain in streams until mature, presumably throughout their lives, while others migrate to a large lake (usually Lake Michigan) before maturity. Adult or maturing non-migratory specimens from the Pigeon River and Ontonogon River are included in the material studied. Most of the specimens from other localities, especially those from the Manistee and other streams of western Michigan, belong to the migratory category.

The rainbows with non-migratory life-history appear indistinguishable from those of migratory habit, when young fish are compared. Adults of the migratory type are commonly larger than the stream-resident fish of the same age. The breeding coloration in both types is essentially alike.

The silvery or "steelhead" coloration in migratory fish is more pronounced than in non-migratory individuals. The immature fish, analogous to the "parr" of salmon, are alike in both types. Fish

with the non-migratory type of life-history apparently change to the adult stage without a conspicuous intervening phase. Those with the migratory type of life-history, on the other hand, pass through a stage analogous to the "smolt" phase of the salmon. They become bright silvery and the parr marks are obscured. The round, black spots are also more or less obscured and many tend to become X-shaped. The dorsal fin and caudal fin become darker. The silvery fish, very different from its former coloration, is often thought by anglers to be a different species, and is called a "steelhead." Migration takes place at or near the time of transformation. Some individuals transform during the fall months, while others transform as late as May.

Ichthyologists have different opinions in regard to the number of recognizable forms of rainbow trout, and the scientific names to be used for such forms. Snyder (1933) uses the name *Salmo irideus* for the large-scaled coast rainbow, which he says (p. 102) has scales in the lateral series numbering 120 to 150 or so. Michigan specimens have scales ranging within these limits, only occasional individuals having scale counts near the upper extreme. Many have approximately 135 scales. Snyder (1933, p. 103) uses the name *Salmo stonei* for the Shasta rainbow (the name *shasta* is regarded by him as synonymous with *stonei*, which has priority) and gives the scale count as 150 to 165. Hubbs (1926, p. 16) points out that both the *irideus* and *shasta* forms have been propagated in Michigan, with more or less crossing in the hatcheries, but that the *irideus* form is predominant in the waters. He regards both forms as subspecies of *Salmo gairdnerii* (Hubbs, 1929, p. 426). Examination of Michigan specimens taken for scale study has shown low scale counts, with occasional exceptions.

Scale Characters

The growth of a rainbow trout scale, during any one season, is marked by widely-spaced circuli (ridges) during the earlier part of the season and by narrowly-spaced circuli during the latter part. According to interpretations of workers on salmonoid scales, rapid growth is attended by wide spacing of circuli, while slow growth is attended by narrow spacing of circuli. Bhatia (1931) has experimentally demonstrated that this is true of rainbow trout scales. By feeding fish very heavily he was able to cause very widely-spaced ridges to be formed. Conversely, by starving fish he was able to produce very narrowly-spaced ridges. Major changes in growth rate are reflected in scale structure. The fast growth of early spring and summer may thus be identified on the scales of wild fish from Michigan localities. A zone of slow growth marks the last growth of the season. Fortunately, the winter period leaves a clear record that is not easily confused with minor disturbances in growth rate such as occur among wild fish.

While the winter mark, or annulus, is recognizable on the scales of Michigan rainbow trout, this is not the only interruption to growth which takes place. A large number of scales had a growth rate interruption or "check" a short distance out from a true winter mark. A specimen with scales in the process of forming such a "check" was taken when transforming to the silvery coloration of the migratory stage. This individual was taken May 27, 1931, in the Au Sable River at Mio. Another specimen taken in Saginaw Bay of Lake Huron on May 29, 1930, proved to have a similar mark close to the margin of the scale. All fish whose scales showed growth interruptions, comparable to these, agreed in having this mark at such distance from the true annulus as to indicate that transformation occurred during late spring. Rich (1920) has presented evidence that scales of young chinook salmon may show a growth-interruption check formed by reason of changes in growth rate with migration from stream to estuary.

Using differences in spacing of circuli, periods of stream growth and lake growth were readily identified on scales of the migratory type rainbows. Catches of fish living in streams and in the Great Lakes allowed verification of the characteristics of both types of growth. Use of mere rapidity of growth as indicative of lake growth may appear questionable, since it may be supposed that some individuals might grow rapidly under stream conditions. Field studies indicate, however, that fish which live in streams throughout life are not able to grow nearly so rapidly as the fish living part of their lives in Lake Michigan, or others of the Great Lakes.

The spawning mark of the rainbow scale, like the corresponding scar on other salmonoid scales, is caused by actual loss of scale material. More of the scale substance is lost from the posterior (exposed) field of the scale than from the anterior (imbedded) field, which is thus a more favorable region for measurement. Loss, probably through absorption, takes place before breeding occurs, while the fish are sleek and show no signs of the destructive changes which often accompany breeding. Resumption of growth following breeding subtends the worn edge of the scale of the breeding fish with new scale material and a permanent scar is recorded. The mark of the first spawning is likely to be less than that of subsequent periods of reproduction and may even be unidentifiable. Males usually have a more severe loss of scale material than females.

Breeding fish do not resume growth until reproductive functions are completed, and are thus later to commence growth in spring as compared to juvenile individuals. Scales of adult breeding fish taken in the Little Manistee River April 11 to 18, 1931, had no new growth, while scales from juvenile fish taken at the same time had added several circuli outside of the recently-formed annulus. The shorter growing season of adult individuals helps to explain a slackening of growth rate after attainment of maturity.

Measurements of the anterior field of scales were used in calculations of lengths of rainbow trout at various years of life. The direct proportion equation was used: *known fish length at time of capture: scale measurement at time of capture: unknown length of fish at end of any one growth season: scale measurement at end of that growth season.* The accuracy of this method was tested from measurements of scales from thirty fish in their first season and twenty-five fish in their second season taken from the Little Manistee River on August 22, 1930. According to this material, the calculated lengths of the fish at one year of age, based on measurements made from scales of fish taken in August of the second season, was 7% too low if the proportion of scale size to fish size was the same in both series. Since the fish grows to some size before scales are formed ("Lee's phenomenon"), lower than true values for calculated lengths for the first year are to be expected. According to Bhatia (1931, p. 49-50), "The rate of growth of the scale relative to the growth of the trout is higher in the earlier stages and proportionate subsequently." The rapid growth of the scale in early life would thus tend to compensate for "Lee's phenomenon." Compensation is indicated by the fact that calculated lengths for fish at the third year were not lower than measured lengths of comparable individuals collected at this age. Fourteen male fish, measured at the end of the third year, when maturing for the first time, averaged 17.51 inches in total length. Seven females averaged 18.60 inches. Calculated lengths for the third year (first year of maturity) based on scale measurements of ten male fish, of the fourth, fifth, sixth and seventh year groups, averaged 19.03 inches. Calculated lengths for the third year (first year of maturity) based on scale measurements of twelve females, of the fourth and fifth year groups, averaged 19.50 inches.

Growth Types

The growth rate of the fish was found to differ with the relative amount of time spent in streams as contrasted to lakes. To facilitate comparisons, it seems advisable to divide the material into seven growth types. A simple scheme of classification, similar to that employed by several investigators of salmon and trout, is used. The symbol *a* designates stream life and *b* designates lake life. Years are separated by a colon. Spawning marks, when sufficiently well-defined to be noted, are marked by the symbol SM at the beginning of the year at which breeding took place. For example, 2a: a plus b: SM indicates a fish which spent two and a part of a third season in a stream, then migrated into a lake and grew for the remainder of the third season, maturing at the beginning of the fourth season. The 97 adult specimens which were studied fall into the following groups:

(1) **1a:a: etc. Stream-resident individuals, which do not migrate to a lake but mature in the stream. While only three adult and maturing specimens were studied, it is not uncommon for rainbow trout in certain streams to mature without having access to a lake.**

(2) **1a:a plus b:SM. First growing season in stream: second started in stream, finished in lake: usually breeding at beginning of third. Seven individuals.**

(3) **2a:b:SM. Two growing seasons in stream: third in lake: usually breeding at beginning of fourth. Eighteen individuals.**

(4) **2a:a plus b:SM. Two growing seasons in stream: third started in stream, finished in lake: usually breeding at beginning of fourth. This group is evidently the most frequent one. Sixty-one individuals.**

(5) **3a:b:SM. Three growing seasons spent in stream: fourth in lake: usually breeding at beginning of fifth. Four individuals.**

(6) **3a:a plus b:SM. Three growing seasons in stream: fourth started in stream, finished in lake: usually breeding at beginning of fifth. Five individuals.**

(7) **4a:a plus b:SM. Four growing seasons in stream: fifth started in stream, finished in lake: breeding at beginning of sixth. One individual.**

Age-Size Relationship

The growth rate of non-migratory specimens was more uniform and less rapid, in later years of life, than the growth rate of the migratory individuals. All of the migratory types were featured by rapid rise in the growth rate immediately following establishment of lake residence. The scales of all old specimens showed a slackening of growth rate, the annual growth increment of the year following first maturity being less than that of the year preceding, and subsequent years showing decrease in the growth increment.

The first year of lake growth is quite evidently the year of greatest length increase for these rainbow trout. It is not exceptional for fish to migrate when two years old and seven inches long (total length) and to return after one season in the lake to spawn at nineteen inches.

Female rainbow trout grow at least as fast as males, according to the material studied. Statistical analysis of measurements of large series of specimens would be necessary to determine whether there are significant differences.

Age at Maturity and Longevity

The specimens which were taken during their first breeding season, together with older specimens which show spawning marks, form the basis for conclusions regarding age at maturity. A few August "parr," taken in streams when in their second growing season, had enlarged reproductive organs and would probably have bred

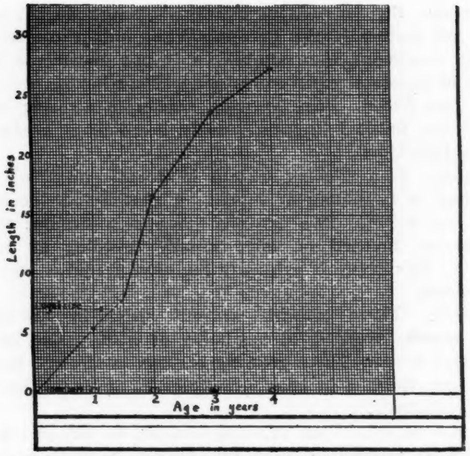

Chart 1 Growth rate of type 2 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

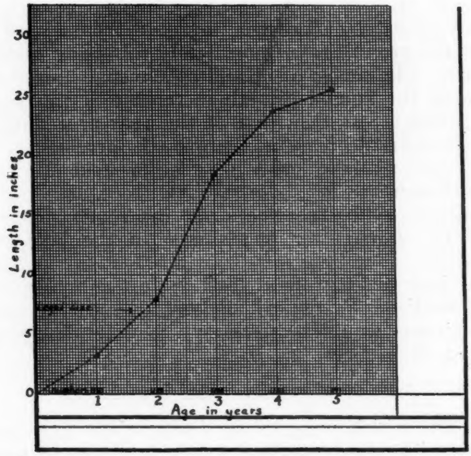

Chart 2. Growth rate of type 3 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

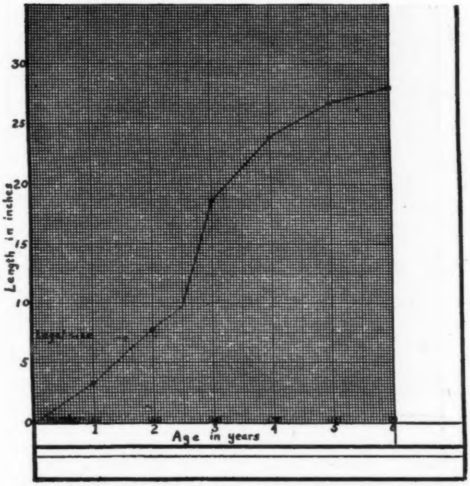

Chart 3. Growth rate of type 4 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

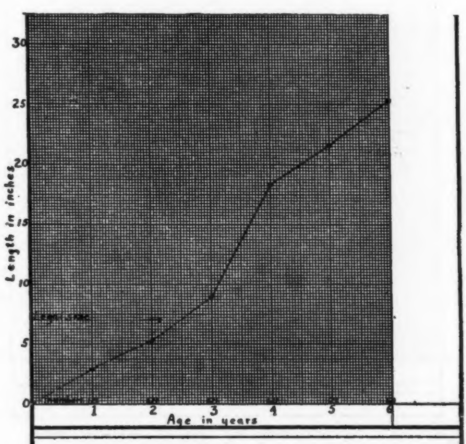

Chart 4. Growth rate of type 5 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

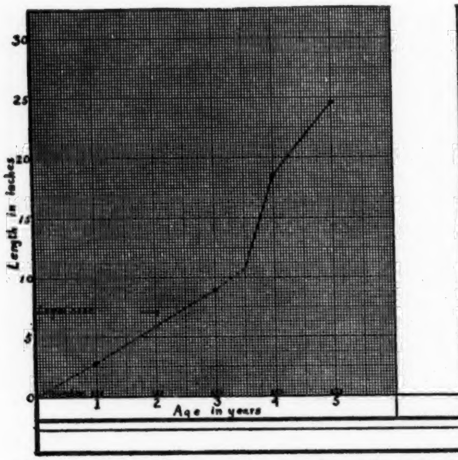

Chart 5. Growth rate of type 6 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

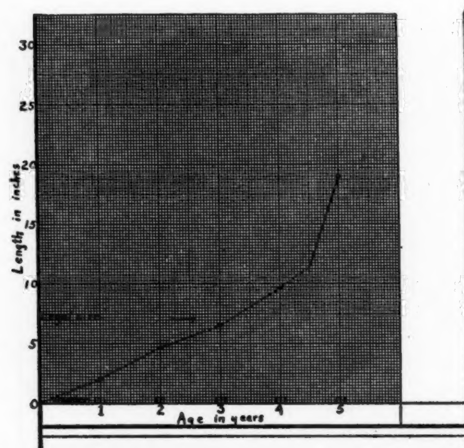

Chart 6. Growth rate of type 7 rainbow trout. (Stream growth shown by dashed line; lake growth by solid line).

for the first time at the beginning of the third growth season. All such individuals were males. The fish of type 2, most of which bred for the first time at the beginning of the third growing season, after spending a large part of the second season under the rapid growth conditions of a lake, represent both males and females. Most of the rainbow trout evidently mature for the first time at three years old (beginning of fourth growing season). A few individuals (type 5, with four individuals) were not mature until four years old (beginning of fifth growing season), while one individual (type 7) did not mature until five years old (beginning of sixth growing season).

Conclusions regarding longevity are warranted when the material studied represents the oldest year-classes which exist. Whether or not there are older fish in Michigan waters than are represented in the material studied is somewhat uncertain. Care was taken to select, from among approximately one thousand individuals held at the Junction Dam station during May, 1931, several of the largest individuals of both sexes. The largest individuals found here (31 inches for both males and females) agreed very closely with the estimated maximum sizes of many hundreds of individuals seen on spawning grounds of the Pere Marquette, Little Manistee, Manistee and Platte Rivers during 1931 and 1932. Individuals larger than the largest ones studied are very scarce in these waters, if they do exist (which is not improbable).

The oldest fish examined were seven winters old. Both of these fish were males. Six males a year younger were included in the series of fish studied. Fish of five winters were frequent; twenty-two specimens representing both sexes were studied. None of the females seen were older than five winters.

The greatest number of breeding years was three for females and four for males (except for one individual evidently representing a fish breeding five times). The possible existence of a longer life and a greater number of breeding years for males as compared to females among wild rainbow trout is suggested by the present study. Observations on spawning grounds indicate that males are more numerous than females. Also, the largest males are of larger size, on the average, than the largest females. The polyandrous mating, two males mating with one female (Greeley, 1932), is suggestive that there may be a correlated greater number of breeding seasons for males.

Growth Rate in Relation to Angling Value

When living under a combined stream and lake habitat, as is the general rule with the rainbow trout in Michigan, this fish grows very rapidly. The angling value of the rainbow resource is affected by the rapidity of growth, for the quicker the growth, the quicker the taking of legal fish becomes possible provided availability remains the same. The duration of stream life affects availability, for

the fish are far more likely to be caught by anglers when they are living in streams rather than when scattered over a large water area of the Great Lakes. An individual fish is exposed to legal capture only when it attains legal size (7 inches) before migration into other waters or when lake life is spent in a lake that may be effectively fished by angling or when it returns to a stream and remains there during a part of the open season.

Some Michigan streams have rainbow trout which do not migrate and these fish have the highest probability of being available throughout life. The "parr" of other rainbow support a large amount of angling, for many of them reach legal size before migration. According to calculated lengths at time of migration for ninety-six rainbows of migratory growth types, ninety-one per cent had reached legal size by the time of migration. In interpretation of the significance of this rather high percentage, however, it should be borne in mind that to be available to anglers, fish must have reached legal size by the end of the open season just before migration, provided their journey was started before the beginning of the next open season. The predominant class, type 4, is made up of fish which migrate during the spring. The average calculated length at migration of the 61 individuals of this group was 9.8 inches (extremes 7.3-13.1 inches). While all of these fish were legal at time of migration, a greater or less number probably were below legal size at closing of the season (September) previous to migration. In certain streams, the percentage of rainbow "parr" which reach legal size at the end of two seasons of growth is not large. A series of 102 fish taken in the Little Manistee river from August 8 to 22, 1930, at the age of one winter (in second growing season) had but 26.2 per cent of fish over legal size. While the sample was doubtless affected by angling, which removed a number of the larger fish, yet it indicates that in this stream a large percentage of rainbow parr are unavailable for angling or are available for but a very short period before migration. The availability of migratory rainbow trout, in Michigan waters, depends, to a large degree, upon the rapidity of growth during the "parr" stage.

LITERATURE CITED

Bhatia, D.

1931. On the production of annual zones in the scales of the rainbow trout (Salmo irideus) I. Journ. of Exper. Zool., Vol. 59, No. 1.

Greeley, J. R.

1932. The spawning habits of brook, brown and rainbow trout and the problem of egg predators. Trans. Amer. Fish. Soc., Vol. 62.

Hubbs, C. L.

1926. A check-list of the fishes of the Great Lakes and tributary waters with nomenclatorial notes and analytical keys. Univ. of Mich. Museum of Zoology, Misc. Publ. No. 15.

1929. Further additions and corrections to the list of the fishes of the Great Lakes and tributary waters. Mich. Acad. Sci. Arts and Letters, Vol. XI.

Rich, W. H.

1920. Early history and seaward migration of Chinook salmon in the Columbia and Sacramento rivers. Bull. U. S. Bur. Fish., Vol. 37.

Snyder, J. O.

1933. California trout. California Fish and Game. Vol. 19, No. 2.

In the following tables adult fish are marked by an asterisk (*) following the sex (M or F).

TABLE 1

Measured total lengths in inches of rainbow trout of O Winter group

Locality	Date	No.	Av.	Extremes
Little Manistee River	August 2, 1930	1	2.63	
Little Manistee River	August 8, 1930	44	2.30	1.75-3.56
Little Manistee River	August 18, 1930	3	3.64	3.31-3.81
Little Manistee River	August 22, 1930	30	2.98	1.88-3.69

TABLE 3

Calculated total lengths in inches of rainbow trout of II winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Meas. L.
Little Manistee River	Apr. 11, 1931	2	M	3.72	6.35	6.69
				(3.09-4.35)	(5.04-7.65)	(5.38-8.0)
Little Manistee River	Apr. 11, 1931	1	—	3.67	7.53	8.5
Little Manistee River	Apr. 16, 1931	1	—	3.62	7.04	7.25
Little Manistee River	Apr. 18, 1931	1	—	4.62	8.47	9.25
Little Manistee River	Aug. 22, 1930	1	F	2.92	5.62	7.88
Little Manistee River	Aug. 23, 1930	1	M	2.98	5.84	10.0
Little Manistee River	Aug. 27, 1930	2	M	2.53	5.41	8.85
				(2.41-2.64)	(5.02-5.79)	(8.69-8.85)
Little Manistee River	Aug. 29, 1930	1	M	1.59	4.48	9.06
Little Manistee River	Aug. 29, 1930	1	F	4.11	5.33	9.25
Pere Marquette River	July 11, 1931	1	M	6.01	9.80	12.25
Pere Marquette River	July 15, 1931	1	F	2.65	7.26	9.75
Pigeon River	Aug. 22, 1931	2	M	3.05	6.06	11.22
				(2.65-3.44)	(4.69-7.42)	(9.19-13.25)
Pigeon River	Aug. 22, 1931	3	F	2.39	6.39	10.46
				(2.07-2.90)	(6.26-6.49)	(9.63-11.0)
Ontonagan River	Aug. 2, 1931	1	M	2.69	6.23	7.25
Ontonagan River	Aug. 2, 1931	1	F	3.16	7.12	9.50
Lake Erie	July 29, 1928	1	—	1.77	5.73	11.26
AuSable River	May 27, 1931	1	—	2.04	7.82	10.38
Saginaw Bay, L. Huron	May 29, 1930	1	M	3.16	7.44	9.13
Manistee River	May 2, 1931	1	M*	5.99	—	18.50

TABLE 2

Calculated total lengths in inches of rainbow trout of I winter group

Locality	Date	No.	Sex	Calculated L. I	Measured L.
Little Manistee River	April 11, 1931	2		3.93 (3.30-4.56)	4.75 (4.13-5.38)
Little Manistee River	August 8, 1930	9	M	2.74 (2.27-3.55)	5.73 (4.88-6.38)
Little Manistee River	August 8, 1930	12	F	2.75 (2.09-3.33)	5.79 (5.0-7.13)
Little Manistee River	August 15, 1930	4	M	2.88 (2.37-3.67)	6.24 (5.50-7.13)
Little Manistee River	August 15, 1930	1	F	3.03	5.50
Little Manistee River	August 17, 1930	1	M	3.54	7.63
Little Manistee River	August 17, 1930	1	—	3.80	7.25
Little Manistee River	August 18, 1930	6	M	3.08 (2.56-3.80)	6.37 (5.38-7.13)
Little Manistee River	August 18, 1930	7	F	3.42 (2.62-4.07)	6.56 (5.75-7.38)
Little Manistee River	August 22, 1930	13	M	3.00 (2.23-4.03)	6.15 (4.94-7.06)
Little Manistee River	August 22, 1930	12	F	3.01 (2.22-3.53)	6.30 (4.81-7.31)
Little Manistee River	August 24, 1930	10	M	3.01 (2.02-3.72)	6.31 (5.06-7.25)
Little Manistee River	August 24, 1930	9	F	3.04 (1.95-3.75)	6.30 (4.56-7.63)
Little Manistee River	August 27, 1930	2	M	3.08 (2.97-3.18)	6.29 (6.19-6.38)
Little Manistee River	August 27, 1930	4	F	3.56 (2.97-4.46)	6.83 (6.06-7.88)
Little Manistee River	August 28, 1930	3	M	3.84 (3.53-4.32)	7.40 (7.06-7.63)
Little Manistee River	August 29, 1930	3	M	4.04 (3.80-4.50)	8.19 (7.25-8.75)
Little Manistee River	August 29, 1930	2	F	3.77 (3.65-3.89)	7.70 (7.06-8.34)
L. S. Br., Pere Marquette R.	August 1, 1930	1	M	3.03	6.19
L. S. Br., Pere Marquette R.	August 1, 1930	3	F	3.61 (3.44-3.88)	6.94 (5.63-7.88)
L. S. Br., Pere Marquette R.	August 3, 1930	2	M	3.76 (3.59-3.93)	8.07 (8.0-8.13)
L. S. Br., Pere Marquette R.	August 3, 1930	2	F	3.42 (3.34-3.50)	7.13 (7.0-7.25)
So. Br. Pere Marquette R.	July 13, 1930	2	M	3.50 (3.46-3.54)	8.38
So. Br. Pere Marquette R.	July 13, 1930	1	—	4.56	9.0
So. Br. Pere Marquette R.	July 31, 1930	1	M	3.32	6.75
So. Br. Pere Marquette R.	July 31, 1930	1	F	4.57	7.88
Pere Marquette River	July 11, 1931	1	M	3.0	7.0
Pere Marquette River	July 11, 1931	2	F	3.51 (2.80-4.21)	7.63 (7.0-8.25)
Pere Marquette River	July 15, 1931	1	—	3.96	9.0
Pigeon River	August 21, 1931	1	M	2.76	9.06
Pigeon River	August 21, 1931	1	F	2.50	6.50
Pigeon River	August 22, 1931	1	M	3.25	8.31
Pigeon River	August 22, 1931	1	F	3.50	8.38
Pine River	July 26, 1930	1	M	4.16	7.50
Pine River	July 26, 1930	1	—	5.50	9.0
Otter River	August 3, 1931	3	M	2.76 (2.22-3.40)	5.88 (5.13-6.38)
Otter River	August 3, 1931	2	F	3.91 (3.51-4.30)	6.72 (6.19-7.25)

TABLE 4

Calculated total length in inches of rainbow trout of III winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Calculated L. III	Measured L.	Type
Little Manistee River	April 11, 1931	1	—	2.43	8.31	8.86	9.75	—
Little Manistee River	April 16, 1931	1	F	3.89	8.37	9.34	10.13	—
Little Manistee River	April 16, 1931	1	M	3.85	7.34	8.44	9.0	—
Otter River	August 3, 1931	1	M	3.69	5.53	7.38	8.13	—
Ontonagan River	August 2, 1931	1	F	2.74	6.76	10.06	12.63	1
Lake Michigan	July 24, 1930	1	F	2.29	6.13	15.32	20.50	3
Little Manistee River	April 13, 1931	2	M*	3.70 (3.38-4.02)	8.16 (7.75-8.57)	—	19.75 (18.50-21.0)	4
Little Manistee River	April 15, 1931	1	M*	3.31	6.84	—	16.38	3
Little Manistee River	April 18, 1931	2	M*	3.36 (3.20-3.51)	6.25 (6.20-6.29)	—	18.88 (18.50-19.25)	4
Muskegon River	April, 1932	1	—	3.20	6.40	—	18.50	4
Manistee River	May 2, 1931	11	M*	3.55 (2.66-4.53)	8.31 (5.83-10.03)	—	17.34 (15.50-20.50)	4
Manistee River	May 2, 1931	1	M*	2.10	7.18	—	18.50	3
Manistee River	May 2, 1931	7	F*	3.10 (2.40-5.41)	8.02 (6.34-9.96)	—	18.61 (16.50-20.0)	4
Manistee River	May 2, 1931	1	F*	5.41	16.45	—	23.75	2

TABLE 5

Calculated total length in inches of rainbow trout of IV winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Calculated L. III	Calculated L. IV	Measured L.	Type
Little Manistee River	April 11, 1931	1	M*	3.25	6.73	16.07	—	23.25	4
Little Manistee River	April 11, 1931	1	F*	3.62	6.74	20.57	—	26.50	4
Little Manistee River	April 19, 1931	1	M*	4.07	18.99	25.15	—	30.25	2
Baldwin Creek	April 17, 1931	1	F*	4.55	9.10	21.49	—	27.50	4
Baldwin Creek	April 17, 1931	1	F*	3.08	8.38	21.62	—	28.25	3
Lake Erie	April 14, 1931	1	M*	2.04	6.71	20.59	26.40	26.97	3
Lake Erie	May 4, 1931	1	F*	1.60	5.09	8.15	16.46	21.85	6
Muskegon River	April, 1932	1	—	3.78	13.86	18.90	—	23.0	3
Muskegon River	April, 1932	1	—	2.51	7.37	23.30	—	29.0	4
Manistee River	May 2, 1931	1	M*	4.25	10.25	22.05	—	26.50	3
Manistee River	May 2, 1931	4	M*	3.52 (2.43-4.46)	8.06 (7.15-8.80)	20.73 (18.42-26.0)	—	25.06 (21.50-29.50)	4
Manistee River	May 2, 1931	3	F*	6.02 (5.33-6.99)	16.75 (16.49-17.30)	24.23 (23.54-25.22)	—	27.92 (27.25-29.25)	2
Manistee River	May 2, 1931	5	F*	3.74 (3.17-5.01)	9.02 (8.10-9.65)	19.20 (17.77-20.79)	—	23.40 (21.50-25.25)	3
Manistee River	May 2, 1931	12	F*	3.63 (2.58-5.55)	7.99 (6.08-10.92)	19.39 (15.98-23.05)	—	25.06 (17.50-26.0)	4
Pine River	June 25, 1932	1	F*	4.10	6.91	18.37	—	24.0	4

TABLE 6

Calculated total lengths in inches of rainbow trout of V winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Calculated L. III	Calculated L. IV	Measured L.	Type
Little Manistee River	April 12, 1931	1	F*	3.36	6.54	16.27	23.19	26.0	3
Little Manistee River	April 16, 1931	1	F*	3.04	6.29	16.85	22.34	26.0	4
Muskegon River	April 11, 1932	1	M*	2.03	4.85	13.33	16.15	20.0	3
Muskegon River	April 14, 1932	1	F*	4.18	5.97	19.12	24.30	26.50	4
Muskegon River	April 20, 1932	1	F*	3.35	9.92	19.11	23.20	27.0	3
Muskegon River	April 29, 1932	1	F*	2.87	8.23	14.92	23.54	24.50	4
Muskegon River	April, 1932	2	—	2.28	6.69	17.23	21.65	24.38	4
				(2.24-2.32)	(6.42-6.96)	(16.24-18.22)	(20.59-22.71)	(23.50-25.25)	
Manistee River	May 2, 1931	2	M*	3.20	9.37	20.37	23.44	26.50	3
				(2.83-3.57)	(7.43-11.30)	(19.65-21.09)	(22.97-23.90)	(25.50-27.50)	
Manistee River	May 2, 1931	1	M*	2.56	7.70	16.38	23.10	31.0	4
Manistee River	May 2, 1931	1	M*	2.24	6.39	10.02	22.64	28.0	6
Manistee River	May 2, 1931	1	F*	2.67	6.48	16.59	24.80	29.0	3
Manistee River	May 2, 1931	6	F*	2.68	7.43	18.28	24.06	27.50	4
				(2.15-3.64)	(6.60-8.59)	(12.84-22.36)	(19.55-29.30)	(23.0-31.0)	
Manistee River	May 2, 1931	1	F*	3.0	5.00	6.80	18.0	22.0	5
Manistee River	May 2, 1931	1	F*	1.92	4.89	6.64	18.33	23.25	6
Manistee River	May 2, 1931	1	F*	2.04	4.65	6.51	9.68	19.0	7

TABLE 7

Calculated total lengths in inches of rainbow trout of VI winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Calculated L. III	Calculated L. IV	Calculated L. V	Measured L.	Type
Little Manistee River	April 5, 1932	1	M*	2.58	6.13	17.11	20.82	26.15	27.13	4
Little Manistee River	April 13, 1931	1	M*	3.75	4.37	14.25	22.87	28.50	30.0	3
Muskegon River	April 1932	1	---	2.26	4.52	7.66	17.71	21.85	25.0	5
Manistee River	May 2, 1931	3	M*	4.04	7.86	19.21	24.04	26.17	27.83	4
				(3.05-5.94)	(5.76-10.45)	(16.25-21.08)	(19.93-27.75)	(22.37-30.09)	(25.0-31.0)	
Manistee River	May 2, 1931	1	M*	3.38	5.97	10.16	18.92	21.31	25.50	4

TABLE 8

Calculated total lengths in inches of rainbow trout of VII winter group

Locality	Date	No.	Sex	Calculated L. I	Calculated L. II	Calculated L. III	Calculated L. IV	Calculated L. V	Calculated L. VI	Measured L.	Type
Manistee River	May 2, 1931	1	M*	3.61	7.23	9.58	17.00	22.79	26.41	27.50	6
Manistee River	May 2, 1931	1	M*	4.18	10.26	21.87	24.91	27.00	28.90	31.00	4

Discussion

(Illustrated by slides.)

MR. TUNISON: Have you had occasion to determine the growth rate of sea trout that have been kept in a stream for five or six years and then went out to the lakes? Do you get an acceleration of growth when they are about six or seven years old?

DR. GREELEY: I have not the material that would establish that, but the rapid year of growth is the year just before maturity—that is when you get the steepest climb. These rainbows go into Lake Michigan, where there is rich food and a big range, as immature fish, and they climb very rapidly in growth rate and then slacken up later. A point I neglected to mention in that connection is that the reproductive organs take a great deal of growth from the fish, that is, metabolism has to take account of the maturing reproductive organs. That is clearly illustrated by getting a series of rainbows in April, as I did on the Little Manistee River; the non-bred fish had already begun growth by April of that year, while the bred fish did not form the winter mark until they got through spawning. In some species in the same locality you get the winter mark at different times, according to whether they are mature or immature. Naturally the older fish is slackening in growth rate.

MR. TUNISON: I was wondering whether a study of the trout over a period of three or four years would show any substantial acceleration in growth at that late age. I think it has been shown by some authorities that you can get that acceleration.

MR. MARKUS: I understand that the fish you took the scales off after they were seven years old were hatchery fish?

DR. GREELEY: They were wild fish. At that time a great number of rainbow trout were propagated from wild eggs taken from the spring run of these fish into the Muskegon River and into the Manistee River. This particular place was on the Manistee. These were Lake Michigan wild fed fish.

MR. MARKUS: You have no idea, then, as to the actual number of years in the case of these fish, other than the scale count?

DR. GREELEY: Nothing except what is general knowledge in the hatcheries of the time at which the rainbow matured; these results checked quite nicely there. As to the greatest length of life, there are one or two published records of rainbows living seven or eight years, but we have very little definite information on individual fish to show how long they can be kept in the hatchery without dying off. Even if you did have that for the hatchery, I do not know whether it would apply to wild fish making their migration before going through the spawning process.

MR. MARKUS: I should like to see the scales of a hatchery fish that has been fed continuously and see what the annuli look like on those scales.

DR. GREELEY: According to this British investigator, Bhatia, a fish can be fed right over the winter and no annuli are produced if they are fed well.

MR. MARKUS: That is exactly what I expected.

DR. GREELEY: It shows you can use scales for growth determination only when they have stopped growing in the winter.

MR. RUSS: Dr. Greeley stated in his talk that he had male rainbows three years old maturing for the first time. Doesn't he find that these males mature earlier than that?

DR. GREELEY: I mentioned I had fish of one growth type which matured in two years. I had fish in that growth type which spent only one and a fraction years in the stream and then migrate to the lake and make a rapid growth, maturing at two years. The increase in the first year after migration is from six, seven and eight inches up to eighteen, nineteen or twenty inches—that is the season just before they mature. But I had males taken in the streams at August of their second year which in their reproductive organs gave indications of going to mature at two seasons without migrating to the lake. So that I think among your non-migratory rainbow you may find, in your wild fish, a number which mature at two seasons rather than three.

MR. RUSS: I asked this question because I have used rainbows at eighteen months—males—that were absolutely satisfactory for breeding purposes.

DR. GREELEY: Were they selected at all?

MR. RUSS: Yes sir.

DR. OSBURN: Is there a considerable difference in the rate of growth between the fishes that live in the streams and do not migrate and those that do migrate into the lakes?

DR. GREELEY: There was a considerable growth rate difference between rainbow, say four years old, which stayed right in the stream and those which had migrated, even when those in the stream were mature fish. I have seen rainbows as small as fourteen and fifteen inches that were over four years old. I have other fish which are only three years old and are nineteen or twenty inches long which migrate. Rapid growth is correlated with range in the Great Lakes just as it is in salmon; they do not grow fast until they get to the ocean.

DR. WIEBE: What would be the picture of the scale if a fish had abundant food for a month or two early in the season, then was starved for the next two months, and then was fed again heavily for a few months after that?

DR. GREELEY: I should think experimental work done on that would give a pretty good clue to what it would be like. But this particular work was not starving and then feeding and then starving and feeding the same fish. When it is done twice on a fish you get that apparent winter mark forming—it looks almost like a winter mark—because the fish has slackened its growth. In other words, what we are determining in fish growth rate investigations is growth cessation mark. The only way we can be sure it is a winter mark is to prove that in a given species they do not slacken in growth at some other period.

DR. WIEBE: The reason I asked that question is this: A couple of years ago I submitted some scales from bass of which we had the absolute age to

within a week or ten days, and these determinations by scale experts disagreed all the way from fifty to one hundred per cent.

DR. GREELEY: I can see how that might well be, because you cannot be sure of ages in fish by just taking every interruption in circuli pattern as a year mark. The only reason I am sure of my year marks on these rainbows is that they grow in a regular way. They do not have any occasion to stop growing in the middle of the year; they go to Lake Michigan and they keep right on through. By the time they transformed to the smolt or migratory stage they had formed a little check, showing they were interrupted. In the case of Pacific salmon that migrates you have that same thing; and also in the change from hatchery fish, planting them in the wild stage a little time before they can find food, it is registered on the scale. The scales are extremely delicate.

MR. MARKUS: I would like to know how you determine the difference between these checks of growth during the winter or summer.

DR. GREELEY: The only check we have on the rainbow spring migration mark—is that the one you have reference to, the time at which they transform?

MR. MARKUS: What I mean is, how do you know the winter annulus from checks, during the growing season.

DR. GREELEY: There are no permanent checks during the growing season on these fish that I have here; also in the adult fish they form a definite spawning mark which is an erosion of the scale. I have a couple of photographs here which, I think, will perhaps save a good deal of explanation on that spawning mark. But at the time we stopped the year's growth the fish spawned along in April before beginning another year's growth, so that there is a heavy erosion of the scale at the end of a year's growth. That checks very nicely, and there is nothing at all in the way of minor interruptions; you are not bothered in these scales with minor interruptions of growth. You find the scale goes right on ahead until the regular slowing down of growth in the fall, and you get a very nice winter mark formed. You can catch fish in, say May and June, which have a winter mark near the meridian just above the circuli or in the growth around it, or you can catch fish right at that time which have a little margin, which checks with where you would expect it. The migration annulus is never very far out from the year's mark preceding it, because the fish which split a year between lake and stream are usually out of the stream by early May and they have only a few weeks spring growth before they migrate. If you calculate length, you find that fish will grow three inches in one winter and seven inches in the next and about nine inches at the time they migrate.

MR. MARKUS: You do not happen to have slides which will show that?

DR. GREELEY: I have two photographs that show the migration interruption, the mark I have called migration check.

MR. MARKUS: I should like very much to see that pointed out.

MR. TERRELL: How long a time expired between each of these lines or circuli?

Dr. Greeley: I cannot say as to that, but I think the work of the British investigator, Bhatia, does show that I have not the information at hand, but the circuli are nothing more than ridges, just about the same as ridges on a thumb print or finger mark, and as the scale gets bigger, more of these ridges are added. The number of ridges added would be in proportion to the amount of scale material there. That point is discussed in that particular paper.

The President: In this connection I may say that in the coastal streams of California and Oregon, in which of course the steelhead is native, it has been found that some of the young steelheads remain in the stream for approximately a year before going to sea, but some remain two years and some three. There is evidence to show, although I do not think it can be said to be demonstrated yet, that in some cases they may not go to sea at all but remain permanently in fresh water. Of course, I refer now to streams in which they have ready access to the sea if they desire to go there.

In connection with the early maturity of the rainbow trout in the hatcheries, I suspect that something of that may be correlated with the rapidity of growth. At our experimental hatchery at Pittsford, we have a stock of rainbows in which the first generation all matured at three years. We selected from among the most rapidly growing fish in the lot and in the next generation a few of them matured at the end of the second year, although the majority matured the third year. It was seen, therefore, that there was some correlation between rapidity of growth and early maturity; that is certainly the case with brook trout, as I think you are all aware.

Scale of adult female rainbow trout, total length 29½ inches, from Manistee River, May 2, 1931. Calculated lengths (inches): 2.76 at first annulus (1); 7.92 at second annulus (2); 9.21 at migration check (M); 18.43 at third annulus (3); 25.99 at fourth annulus (4). The scale shows spawning marks at 4th and 5th annuli.

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SUMMARY REPORT OF CRUSTACEA USED AS FOOD BY THE FISHES OF THE WESTERN END OF LAKE ERIE

LELA A. EWERS

Formerly Assistant Biologist Bureau of Scientific Research
Ohio Division of Conservation

TABLE 1

*Summary of Contents of Forty Largemouth Black Bass *(Aplites salmoides)* Stomachs from Fish taken between June 21 and July 31, 1929, from various Stations in or near Lake Erie.

	29 Fish, 10 to 83 mm. Total Length				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	28	96.5	87.1	9.7	50
Copepoda	20	68.9	38.8	4.3	50
Cyclops	18	62.	28.9	1.6	8
C. americanus	9	31.	12.6	0.57	3
C. leuckarti	2	6.8	.86	.19	3
C. bicuspidatus	3	10.3	6.	.1	1
C. serrulatus	3	10.3	2.4	.24	5
Diaptomus	5	17.2	6.2	2.5	50
D. siciloides	2	6.8	2.7	.4	10
D. oregonensis	1	3.4	3.33	.06	2
Epischura lacustris	4	13.8	3.4	.2	2
Cladocera	18	62.	43.	5.4	38
Sida crystallina	8	27.5	14.	1.2	13
Daphnia	1	3.4	.41	.06	2
Diaphanosoma leuchtenbergianum	1	3.4	.2	.06	2
Bosmina	7	24.1	10.5	1.38	33
B. longirostris	6	20.6	8.7	1.3	33
B. longispina	1	3.4	1.8	.03	1
Chydorus sphaericus	2	6.8	1.3	.10	2
Alona	4	13.8	4.22	.44	7
A. costata	3	10.3	3.6	.2	3
A. guttata	1	3.4	.51	.24	7
Scapholeberis mucronata	3	10.3	3.	1.4	30
Pleuroxus procurvatus	1	3.4	3.4	.03	1
Amphipoda	3	10.3	5.2	.10	1
Gammarus	2	6.8	3.5	.07	1
Hyalella knickerbockeri	1	3.4	1.7	.03	1
Insecta	3	10.3	1.38	.17	2
Chironomodae (Chironominae)	2	6.8	1.2	.10	2
Corixidae (Corixa)	1	3.4	.17	.06	2
Fishes	4	13.8	11.4	.207	2
Cyprinus carpio	1	3.4	3.2	.03	1
Debris	1	3.4	.06	—	-

*Eleven fish had no food in their stomachs and were not included in the above table.

This study of the food of the largemouth black bass covers only forty fish taken mainly from one locality in Lake Erie.** Only

**One of a series of papers dealing with the Lake Erie Cooperative Hydrobiological Survey in 1926, 1927, 1928, 1929 and 1930. Laboratory facilities for this report furnished through the courtesy of Dr. R. C. Osburn, Director, Stone Research Laboratory, Put-in-Bay, Ohio.

one fish which contained any food in its stomach was longer than 36 mm., total length. Table 1 shows that 87.1 per cent of the food was Crustacea, of which 38.8 per cent was Copepoda, 43 per cent Cladocera and 5.2 per cent Amphipoda. Gammarus was not found in any fish which measured less than 33 mm. total length. Fishes made up 11.4 per cent of the food but were only found in 13.8 per cent of the fish stomachs which contained any food.

Detailed food studies have been completed for 1203 young fish

TABLE 2

***Summary of Contents of One Hundred and Eight White Bass *(Lepibema chrysops)* Stomachs from Fish taken by Seine at Eight Stations in Lake Erie from June 25 to July 23, 1929.**

	One Hundred and Six Fish 17 to 150 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Fish	5	4.7	4.4	.08	4
Notropis	3	2.8	2.4	.04	3
N. hudsonius	1	.9	.9	.009	1
N. atherinoides	2	1.8	1.44	.028	2
Lepibema chrysops	1	.9	.37	.009	1
Notemigonus crysoleucas crysoleucas	1	.9	.8	.018	2
Insecta	9	8.4	1.3	.05	2
Chironomidae	4	3.8	1.2	.04	2
Chironominae	2	1.8	.4	.01	1
Ceratopogoninae	1	.9	.37	.009	1
Ephemeridae	2	1.8	.12	.009	1
Ephoron	1	.9	1.2	.009	1
Corixa (Corixidae)	1	.9	trace	trace	—
Midge pupae	1	.9	trace	trace	—
Crustacea	104	98.1	91.5	81.2	1112
Copepoda	95	89.6	62.5	55.7	405
Cyclops	48	45.2	9.1	6.	99
C. leuckarti	35	33.	7.01	4.1	99
C. bicuspidatus	1	.9	.009	.009	1
C. americanus	5	4.7	.67	.21	10
Diaptomus	70	66.3	28.6	40.7	404
D. siciloides	21	19.8	.89	1.6	18
D. sicilis	3	2.8	.08	.1	5
D. oregonensis	24	22.6	1.39	1.1	23
Epischura lacustris	65	61.3	23.6	7.7	340
Cladocera	84	79.2	29.1	25.5	772
Leptodora kindtii	76	71.7	18.9	5.7	71
Daphnia	16	15.	2.13	13.8	765
D. (retrocurva)	12	11.3	2.05		
Diaphanosoma leuchtenbergianum	38	35.8		5.2	97
Bosmina longirostris	6	5.6	2.5	.12	7
Sida crystallina	15	14.1	1.03	.35	9
Copepoda (parasitic)		1.8	3.2		
Argulus stizostethi	2	1.8	.02	.009	1
Plant fragments	1	.9	.04	—	—
Debris	8	7.5	.68	—	—

*Two fish had no food in their stomachs and were not considered in the above table.

representing twenty-four species. Professor M. W. Boesel, formerly Assistant Biologist, Ohio Division of Conservation, identified the insects.

No evidence of vegetable food was found. No striking change in the type of food taken by different sizes of fish was noted. However, the one fish (whose stomach contents was studied) which measured more than 36 mm. total length had eaten 92 per cent fish, 2 per cent Insecta, 1 per cent Crustacea (Gammarus) and 2 per cent debris. No small Crustacea were found. If more fish of this length or larger had been examined we might find that there is a decided change of food existing. The fish in question measured 83 mm., total length.

Table 2 shows that 91.5 per cent of the food of the white bass studied consisted of small Crustacea; 62.5 per cent of which was Copepoda, and 29.1 per cent Cladocera. 1.3 per cent of the food was Insecta and 4.4 per cent Fishes with minute quantities of other foods. Of the Copepoda, Epischura lacustris and Diaptomus and of the Cladocera, Leptodora kindtii, form the larger part of the food. Epischura and Leptodora kindtii are the largest representatives of

TABLE 3

***Summary of Contents of Seventy Nine Whitefish *(Coregonus clupeaformis)* Stomachs from Fish Taken from April 15 to June 29, 1929 and 1928, at Various Stations in Lake Erie.**

	Fifty-eight Whitefish 10-31 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	49	84.4	76.5	6.3	83
Copepoda	47	81.	68.	5.2	82
Cyclops	38	62.8	49.7	4.4	82
C. bicuspidatus	23	49.6	28.1	2.2	27
C. leuckarti	1	1.7	.17	.017	1
Diaptomus	9	15.5	6.9	.62	24
D. oregonensis	1	1.7	.08	.017	1
Epischura lacustris	1	1.7	.42	.017	1
Copepodid nauplii	3	5.1	4.2	.47	16
Cyclops nauplii	1	1.7	.77	.05	3
Diaptomus nauplii	2	3.4	1.7	.38	16
Cladocera	10	17.2	6.1	1.	43
Daphnia	5	8.6	2.6	.19	3
D. (retrocurva)	1	1.7	.55	.017	1
D. pulex	2	3.4	.98	.08	3
Bosmina	3	5.1	.14	.06	2
B. longirostris	1	1.7	.0008	.017	1
Diaphanosoma leuchtenbergianum	1	1.7	1.5	.74	43
Debris or digested Food	3	5.1	23.4	—	—

*Twenty-one fish which were examined had no food in their stomachs and were not included in the above table.

their respective groups found commonly in the shallower waters of the western end of the lake where these fish were taken. They were not taken in such large numbers as Diaptomus but because of their larger size made up quite a large percentage of the food contents. Daphnia retrocurva was taken in large quantities in some localities.

A summary of the food contents of nine fish, taken at one place and measuring from 110 to 150 mm. total length, shows an interesting point. Four of these fish (44.4 per cent) had taken mostly fish as their food so that 42.5 per cent of the total amount of food taken by the nine fish consisted of fish. Still the fact remains that 55.6 per cent of these large fish had taken no fish at all and their food mainly consisted of small Crustacea. Insecta play only a very small role in the food of any White bass studied.

This study of the food of the young Whitefish is one of the few investigations on this subject and is more detailed than any former research. Young fish taken in meter nets from the open waters of Lake Erie from April 15 to June 29, 1928 and 1929.

The investigation shows that practically 100 per cent of the food taken by these larval Whitefish consisted of Crustacea since

TABLE 4

Summary of Fifty-seven Trout-Perch *(Percopsis omiscomaycus)* Stomachs from Fish Taken from Lake Erie July 20 and August 29, 1929.

Food Organisms	Fifty-four Fish 24 to 48 mm. Total Length — Frequency of Occurrence: No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	54	100.	94.3	35.2	225
Copepoda	42	77.7	44.1	28.2	225
Cyclops	23	42.6	35.4	26.8	224
C. americanus	22	40.7	11.7	6.4	65
Diaptomus	11	20.3	2.5	.3	4
D. oregonensis	7	12.9	.83	.2	2
Epischura lacustris	25	46.3	6.2	1.03	7
Cladocera	32	59.2	48.3	7.5	44
Leptodora kindtii	28	51.8	30.2	3.2	16
Daphnia (retrocurva)	27	50.	18.	4.4	39
Letona setifera	1	1.8	.1	.02	1
Amphipoda	1	1.8	1.8	.02	1
Hyalella knickerbocheri	1	1.8	1.8	.02	1
Insecta	4	7.4	5.7	.2	4
Tricoptera larva	1	1.8	.8	.03	2
Chironomidae	4	7.4	4.8	.16	3
Chironcmidae larvae	4	7.4	·	.14	2
Chironomidae pupa	1	1.8	1.5	.01	1
Chironominae larvae	3	5.5	2.5	.09	2
Tanypinae larva	1	1.8	.46	.02	1

*Three fish in this group had no food in their stomachs and were not considered in the above table.

the actual estimated percentage of Crustacea found in the stomachs was 76.5 per cent and the remainder of the contents was debris or digested food which was not identifiable. There was no evidence of vegetable food present. Of the 76.5 per cent Crustacean food 68 per cent or more was Copepoda. This means that at least 88.9 per cent of the identifiable food of these young Whitefish was Copepoda and 7.9 per cent or more was Cladocera. 64.9 per cent of the identifiable food was Cyclops, while Cyclops bicuspidatus was the predominating species. An interesting observation here is that a comparatively large number of adult female Copepoda were taken which might indicate that the ova was the attractive part of the Copepod at which the fish snatched and that at times only the ova were gained. Observations made on the whole digestive tract indicated that ova are not digested, so probably do not serve as food but show that the fish had taken or had attempted to take Copepoda.

The yolk sac may disappear when the total length of the fish is but 10 mm. and again it may still be large and hard at a length of 14 mm. Four or five individuals which still had the yolk sac

TABLE 5

***Summary of Contents of Stomachs of Forty-one Golden Shiners *(Notemigonus crysoleucas)* Taken by Seine and Peterson Trawl from July 15, 1929, to July 27, 1929, at Six Different Stations in Lake Erie.**

	Thirty-four Fish, 15 to 49 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	30	88.2	78.8	1.9	22
Copepoda	11	32.3	17.2	.2	2
Cyclops	10	29.4	14.	.14	2
C. bicuspidatus	1	2.9	.73	.03	1
Diaptomus	3	8.8	2.6	.03	1
Epischura lacustris	1	2.9	.5	.03	1
Cladocera	24	70.5	61.6	3.7	22
Daphnia	6	17.6	12.4	.33	8
D. (retrocurva)	3	8.8	7.8	.29	8
Leptodora kindtii	6	17.6	15.2	.26	2
Diaphanosoma leuchtenbergianum	12	35.2	17.	2.8	22
Chydorus sphaericus	1	2.9	.76	.1	5
Insecta	4	11.7	7.2	.08	1
Chironomidae	1	2.9	2.9	.03	1
Diptera	1	2.9	2.9	—	—
Mycetophilidae	1	2.9	.44	.03	1
Debris	12	35.2	14.	—	—

*Seven out of the Forty-one fish which were examined had no food in their stomachs and were not considered in the above table.

partially filled, showed the presence of debris or digested food in the stomach but no identifiable food was found in any individual which still retained the yolk sac with an appreciable amount of food in it.

The Trout-perch studied were collected at four different stations in the southwest portion of Lake Erie. These stations were located between the south end of South Bass Island and the mouth of the Maumee River.

The food as shown by Table 4 consists of 94.3 per cent Crustacea and 5.7 Insecta. The Crustacea consist of 44.1 per cent Copepoda, 48.3 per cent Cladocera and 1.8 per cent Amphipoda. There is a smaller number of species represented than usual in such a study, but this is probably due to the fact that practically all fish

TABLE 6

***Summary of Contents of One Hundred Thirty-four Yellow Perch *(Perca flavescens)* Stomachs from Fish Taken from Lake Erie During the Summer of 1929. These Fish Measured from 14 to 79 mm. Total Length.**

	One Hundred Twenty-seven Fish, 14 to 79 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	127	100.	94.3	87.7	1480
Copepoda	117	92.1	66.6	34.4	235
Cyclops	89	70.	32.1	14.9	137
C. americanus	22	17.3	5.1	1.09	24
C. leuckarti	47	37.	7.7	7.9	139
C. bicuspidatus	34	26.7	5.2	1.3	17
Diaptomus	71	55.9	20.4	13.2	135
D. sicilis	13	10.2	1.1	1.2	40
D. siciloides	5	3.9	2.1	.41	27
D. minutus	1	.7	.06	.007	1
D. ashlandi	3	2.3	.21	.09	10
D. oregonensis	20	15.7	2.3	1.9	50
Epischura lacustris	44	34.6	12.9	6.1	235
Cladocera	84	66.1	26.6	53.5	1463
Diaphanosoma leuchtenbergianum	45	35.4	6.8	5.6	95
Leptodora kindtii	24	18.9	3.9	.6	18
Bosmina	19	14.9	3.9	32.5	1427
B. longirostris	17	13.3	3.	32.1	1427
Sida crystallina	16	12.6	1.9	1.05	36
Daphnia	32	25.2	8.7	13.2	260
D. (retrocurva)	21	16.4	7.7	13.1	260
Fish	1	.7	.47	.007	1
Insecta	2	1.5	.7	.02	2
Corixidae (Corixa)	1	.7	.2	.007	1
Chironomidae (Chironominae)	1	.7	.18	.007	1
Odonata (Zygoptera)	1	.7	.39	.007	1
Debris	10	70.	4.4	—	—

*Seven fish of this group had no food in their stomachs and were not considered in the above table.

were taken the same day. Different species predominate at different times of year. The most common species of Crustacea found were Cyclops americanus, Diaptomus oregonensis, Epischura lacustris, Leptodora kindtii and Daphnia retrocurva. The two fish taken August 29 were not enough to give much data as the one had no food and the other had only Amphipoda.

Upon examining the food of these fishes you are at once impressed with the fact that practically all the food is broken into fragments or partially digested. It is very difficult to count, with any degree of accuracy the number of individuals eaten by the fish in most cases. This may account for the very low average number of animals eaten as given in the table; also for the low number of individuals eaten by any one fish.

As shown by the table 78.8 per cent of the food eaten was found to be Entomostraca; 17.2 per cent was Copepoda, 61.6 per cent Cladocera, 7.2 per cent Insecta and 14 per cent debris or completely digested food. The animals which formed more than 10 per cent of the food were: Cyclops (14 per cent), Daphnia (12.4 per cent), Leptodora kindtii (15.2 per cent) and Diaphanosoma leuchtenbergianum (17 per cent). No Insecta were found in any fish measuring less than 34 mm. total length.

TABLE 7

***Summary of Contents of Nineteen Log Perch *(Percina caprodes)* Stomachs from Fish Taken from July 23, 1929, at Five Different Stations in Lake Erie.**

	16 Fish, 21-53 mm. Average 33.9 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	15	93.7	85.8	200.8	953
Cladocera	15	93.7	85.3	200.3	953
Bosmina	4	25.	19.3	152.8	950
Sida crystallina	3	18.7	4.06	.8	8
Daphnia (retrocurva)	5	31.2	21.06	30.8	221
Diaphanosoma leuchtenbergianum	11	68.7	33.3	15.3	70
Leptodora kindtii	1	6.2	1.3	.1	2
Copepoda	3	18.7	.5	.3	3
Cyclops	2	12.5	.3	.2	3
Diatomus	1	6.2	.1	.06	1
Insecta	3	18.7	8.6	.8	7
Ephemerida	1	6.2	4.3	.2	4
Baetinae	1	6.2	3.7	.1	3
Chironomidae	2	12.5	.5	.3	2
Coleoptera larva	1	6.2	.6	.06	1
Debris	5	31.2	5.5	—	—

*Three of the nineteen fish did not contain food in their stomachs and were not considered in the above table.

Yellow perch collected from fifteen different stations with a total of nineteen collections taken. Collections were made at four stations on different dates to see if the food at the same place varied at different dates.

The food of the Yellow perch seemed to consist almost entirely of small Crustacea. Of the 94.3 per cent of Crustacea 66.6 per cent were Copepoda and 26.6 per cent Cladocera. Only three fish or 2.3 per cent of the total number of fish took any food other than Entomostraca. These three were all over 40 mm. in total length. These studies did show a change in the presence and absence of different species at different dates. Cyclops americanus was found rather commonly in the food of fish taken the last of June, while rarely found in July collections. Cyclops leuckarti increases in numbers as Cyclops americanus decreases. Cyclops bicuspidatus was not so plentiful in July collections except in deep water. Leptodora kindtii was not so common in June as in July. These changes correspond with observations which have been made upon the changes in the plankton.

The number of fish examined was not large enough to make any very definite conclusions, but the data obtained showed that Entomostraca was the principal article of diet for the young fish. In-

TABLE 8

Summary of the Stomach Contents of Fourteen *Pomoxis annularis* (White Crappie) Taken at Four Different Stations in the Southwest End of Lake Erie from July 22 to August 19, 1929.

	14 Fish 32 to 75 mm. Average 49.7 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	14	100.	96.	204.7	634
Copepoda	14	100.	62.3	132.6	457
Cyclops	12	85.7	28.9	72.6	242
C. leuckarti	11	78.5	8.1	17.1	56
C. americanus	7	50.	5.2	17.9	95
Diaptomus	14	100.	24.6	53.9	215
D. oregonensis	12	85.7	4.6	13.5	94
D. minutus	1	7.1	.1	.2	3
Epischura lacustris	7	50.	7.7	6.	26
Cladocera	14	100.	32.6	72.2	205
Daphnia	10	71.4	9.4	22.	75
D. (retrocurva)	9	64.2	3.9	9.7	37
Diaphanosoma leuchtenbergianum	13	92.8	10.6	42.2	128
Bosmina longirostris	3	21.4	.09	.6	5
Leptodora kindtii	8	57.1	3.7	4.6	35
Insecta (Chironomidae) Chironominae larvae)	2	14.2	.4	.1	1
Debris	5	35.7	3.5	—	—

sects were not found in any individual under 35 mm., total length, and were found in only 18.7 per cent of the stomachs examined. In brief, the food consisted of Crustacea 85.8 per cent; of which 85.3 per cent were Cladocera and .5 per cent Copepoda.

These results correspond, so far as they go, with those given by Turner (1921) in which he says the younger specimens subsist mainly upon Entomostraca, intermediate forms upon Insects and Entomostraca, while larger specimens are more complicated, but Entomostraca are continued as a constant though small item, and Insect larvae form the principal constituent. The largest individual which I examined was 53 mm., total length, so not much can be said of the larger forms.

The food as shown by Table 8 consisted of 96 per cent Crustacea, of which 62.3 per cent was Copepoda (Cyclops 28.9 per cent, Diaptomus 24.6 per cent, and Epischura lacustris 8.7 per cent) and 32.6 per cent Cladocera. There was one Insect larva in each of two fish. There seemed to be no change of food in the different sizes of fish studied and very little difference at different stations.

TABLE 9

Summary of Contents of Twenty-nine *Pomoxis sparoides* (Black Crapple) Stomachs from Fish Taken by Seine, from July 22 to August 19, 1929, in the Southwest Portion of Lake Erie and Vicinity.

	29 Fish, 40-70 mm. Average 53.4 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	29	100.	83.72	204.9	919
Copepoda	28	96.5	58.21	121.4	694
Cyclops	26	89.6	26.7	62.3	458
C. leuckarti	23	79.3	16.5	35.8	155
C. americanus	2	6.9	.5	1.4	22
Diaptomus	24	82.7	21.51	50.3	341
D. oregonensis	16	55.2	4.5	8.4	57
D. sicilis	2	6.9	.06	.1	2
Epischura lacustris	20	69.	7.5	8.8	71
Cladocera	25	86.2	25.51	83.4	460
Bosmina longirostris	13	44.8	10.8	52.	452
Ceriodaphnia reticulata	1	3.4	.02	.13	4
Diaphanosoma leuchtenbergianum	10	34.4	3.03	20.4	179
Leptodora kindtii	6	20.6	2.9	.8	8
Daphnia	12	41.3	2.4	7.3	83
D. (retrocurva)	11	37.9	1.06	3.1	22
D. pulex	3	10.3	.86	2.7	61
Sida crystallina	7	24.1	4.1	1.9	14
Insecta (Chironomidae Chironominae)	3	10.3	1.4	.04	1
Fish remains	1	3.4	1.4	.03	1
Algae (Diatoms)	1	3.4	.03	—	-
Debris	16	55.2	13.4	—	-

The food of the Black crappie consisted almost wholly of Entomostraca as the summary shows 83.72 per cent Entomostraca, 1.4 per cent Insecta, 1.4 per cent Fish, .03 per cent Algae and 13.4 per cent Debris. Three fish had eaten of Insects, one of Fish and one of Algae.

TABLE 10

Summary of Contents of Sixty-two *Notropis atherinoides* (Lake Shiner) Stomachs from Fish Taken by Peterson Trawl and Meter Net from April 18, 1929, to August 31, 1929, and October 3, 1928, at Ten Different Stations in Lake Erie.*

	58 Fish, 31-90 mm. Average 61.3 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	48	82.7	66.7	61.7	600
Copepoda	26	44.8	29.5	11.6	134
Cyclops	23	39.6	19.0	5.1	55
C. bicuspidatus	19	32.7	13.6	3.9	55
Epischura lacustris	2	3.4	.05	.12	5
Limnocalanus macrurus	1	1.7	.08	.05	3
Diaptomus	14	24.1	10.4	6.1	93
D. ashlandi	9	15.5	1.8	1.1	22
D. sicilis	7	12.0	2.08	1.4	21
Cladocera	28	48.2	37.1	50.1	600
Leptodora kindtii	14	24.1	14.9	4.8	62
Daphnia (retrocurva)	8	13.8	8.4	42.6	600
Diaphanosoma leuchtenbergianum	5	8.6	3.4	2.5	70
Insecta	13	22.4	12.4	.9	20
Chironomidae (Chironominae pupae)	8	13.8	7.2	.7	20
Ephemerida (Epheminae)	1	1.7	1.7	fragments	
Aphididae	1	1.7	.17	.01	1
Carabidae	1	1.7	.17	.01	1
Staphylinidae	2	3.4	.6	.05	2
Cicadellidae	1	1.7	.17	.01	1
Ichneumonidae	1	1.7	.1	.01	1
Formicidae	1	1.7	.5	.01	1
Debris	22	37.9	20.6	—	—

*Four of these fish had no food in their stomachs and were not considered in the above table.

The food in general consisted of 66.7 per cent Entomostraca, 12.4 per cent Insecta and 20.6 per cent debris. The food in these fish was in fragments. The food in fish taken at different stations varied considerably. At one station Cyclops bicuspidatus was practically the only food taken. Fish taken at a different station but about the same time of year had eaten 16 per cent Cyclops, but 49.8 per cent Diaptomus and 32.3 per cent Insecta. Whether this is due to selection or to difference in the food present I do not know.

Collections taken in April show a predominance of Cyclops bicuspidatus, Chironominae pupae and Diaptomus, while collections taken during August and October show a predominance of Leptodora kindtii, Diaphanosoma leuchtenbergianum and Daphnia retrocurva.

This probably is due to the fact that there are pulses of these forms at these dates or to the disappearance of other forms.

These fish were taken from ten different stations. The majority of the fish were from one station at the south end of South Bass Island. These fish varied in size from 15 mm. to 56 mm. This afforded an opportunity to study the food of fish of different sizes from the same station and same date.

TABLE 11

Summary of Contents of One Hundred and Twenty-six Sheepshead *(Aplodinotus grunniens)* Stomachs from Fish taken from Lake Erie and Vicinity during July and August, 1929.*

	108 Fish, from 14 to 110 mm. Average 36.4 mm. Total Length				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Crustacea	99	91.6	70.4	7.6	40
Copepoda	82	75.9	47.6	6.2	38
Cyclops	73	67.6	37.6	5.1	32
C. albidus	45	41.6	10.9	2.7	20
C. americanus	30	27.7	8.5	.93	12
C. leuckarti	20	18.5	4.5	.35	5
Diaptomus	23	21.3	3.7	.44	7
D. oregonensis	2	1.8	.32	.03	3
Epischura lacustris	16	14.8	5.8	.83	17
Cladocera	44	40.7	19.5	1.2	14
Daphnia (retrocurva)	11	10.2	4.4	.34	8
Leptodora kindtii	26	24.	11.5	.57	12
Diaphanosoma leuchtenbergianum	1	.9	.6	.03	4
Latona setifera	2	1.8	.09	.02	2
Sida crystallina	1	.9	.06	.009	1
Ostracoda	1	.9	.02	.009	1
Amphipoda	4	3.7	.92	.06	4
Hyalella knickerbocheri	1	.9	.04	.009	1
Gammarus	2	1.8	.7	.04	4
Isopoda (Asellus communis)	1	.9	.37	.02	2
Nematoda	2	1.8	.03	.03	3
Insecta	38	35.2	24.4	4.06	116
Chironomidae	29	26.8	14.8	3.8	116
Chironominae	15	13.8	6.4	3.	116
Tanypinae	16	14.8	6.7	.6	22
Ceratopogoninae	2	1.8	.05	.02	1
Ephemerida	11	10.2	6.5	.16	4
Hexagenia	7	6.4	4.7	.08	2
Ephemera	4	3.7	.78	.06	4
Ephoron	1	.9	.88	.009	1
Caenis	1	.9	.16	.009	1
Trichoptera larvae	5	4.6	1.1	.05	2
Corixidae	3	2.7	1.3	.02	1
Palmacorixa	2	1.8	1.01	.018	1
Fish	2	1.8	1.17	.03	3
Cyprinids	1	.9	.07	.27	3
Debris	16	14.8	3.7	—	-

*Of the one hundred and twenty-six examined, eighteen had no food in their stomachs and were not included in the above table.

The above table shows that Sheepshead eats a variety of foods. (See Table). Further study shows that the proportions of various foods varies with the size of the fish. Sheepshead under 25 mm. do not eat Insects, while fish between 26 and 35 mm. eat 81.7 per cent Entomostraca and 16.3 per cent Insecta and fish between 36 and 45 mm. eat 66.8 per cent Entomostraca and 22 per cent Insecta and the fish over 45 mm. in length eat 19.9 per cent Crustacea or 14.1 per cent Entomostraca and 70.83 per cent Insecta, with some other foods entering into the diet. Only four fish which measured 80 mm. or more, were examined and these had eaten no Entomostraca, so it might be that Entomostraca drop out of the diet.

All of these fish were taken from July 20 to August 23, 1929, so not much was noted in the food eaten at different dates. Different stations may have had some influence as the four fish from east of Locust Point had eaten no Entomostraca, although none were over 67 mm. in length.

TABLE 12

*Summary of One Hundred and Eleven *Stizostedion*** Stomachs from Fish taken from Lake Erie from June 27 to September 29, 1929.

	Eighty-seven Fish from 24-190 mm. Averaging 59.3 mm.				
	Frequency of Occurrence				
Food Organisms	No. of stomachs	% of total No. of stomachs	Ave. % of food by volume (est.)	Ave. No. of animals	Greatest No. of animals in any one stomach
Etomostraca	63	72.4	64.63	5.8	61
Copepoda	21	24.1	9.9	1.7	34
Cyclops	4	4.6	2.2	.2	6
C. americanus	1	1.1	.1	.01	1
C. leuckarti	1	1.1	.4	.07	6
Diaptomus	1	1.1	.05	.01	1
Epischura lacustris	17	19.5	7.6	1.5	34
Cladocera	58	64.3	50.7	4.02	61
Leptodora kindtii	36	41.3	28.3	2.18	60
Daphnia (retrocurva)	18	20.6	4.6	1.	22
Diaphanosoma leuchtenbergianum	10	11.5	4.9	.2	6
Sida crystallina	7	8.	7.	.4	30
Bosmina	1	1.1	.07	.03	3
Insecta (chironomidae)	7	8.	4.7	.09	2
Chironominae	7	8.	4.4	.08	1
Tanypinae	1	1.1	.2	.01	1
Chironomus pupae	1	1.1	1.1	.01	1
Debris	4	4.6	3.1	—	-
Fish	25	28.7	27.28	.20	2
Notropis atherinoides	1	1.1	1.1	.01	1
Notropis heterolepis heterolepis	1	1.1	1.1	.01	1
Noturus flavus	1	1.1	1.03	.01	1

*Twenty-four fish had no food in their stomachs and were not included in the above table.

**At the time of this investigation the young sauger were separated from the young pike-perch, but the blue pike-perch were not distinguished from the yellow pike-perch. In a later and more detailed report we propose to do this. (This table speaks for itself—nothing striking)—Fish were taken from 15 stations.

MORE PROBLEMS OF POND-FISH CULTURE

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Ohio has rechristened her establishments where fish are produced. The one at Put-in-Bay, which incubates and hatches the artificially-fertilized eggs of the whitefish and pickerel, is still called a hatchery. The system of twelve inland establishments used for the production of fingerling game fish, are now called State Fish Farms, a name far more appropriate to the varied tasks of developing and maintaining brood-stocks, providing special breeding facilities, utilizing fertilizers, feeding extensively, and harvesting an annual crop.

It has been shown that small-mouth bass spawn on a rise in temperature and that a series of new beds of eggs are deposited by the breeders in a spawning pond on each of several successive rises in temperature. (Langlois, T. H., 1932, p. 162.) It has been found that the eggs within the ovaries of a female small-mouth bass are of three distinct sizes early in the season (Reighard, J. E., 1904, p. 21), and that such a female bass spawns on each of several successive rises in temperature, and it is assumed that eggs of a single size group are deposited at each spawning. A table of data on the spawning of small-mouth bass in several ponds of the Ohio Fish Farms is appended which establishes two additional facts about the spawning of the species, namely, that spawning begins at different temperature points at different parts of its range, and that each successive spawning begins at a temperature point higher than that at which the previous spawning had begun, as has been found to be true for the oysters of Barnegat Bay (Nelson T. C., 1928, p. 152).

The desirability of controlling the temperature of the water of the breeding pond is obvious, for if the bass are activated into spawning by a rise in temperature, their spawning can be delayed by preventing such an occurrence, and if the time of spawning can be controlled it is possible to have the rearing ponds in proper condition before the fry are transferred to them. At the Xenia Fish Farm we have established conditions whereby it is possible to add either cold or warm water to the two spawning ponds and as the water from the two sources can be mixed before adding, any temperature from 60° to 75° can be utilized.

During the spawning season of 1933 we had an unusual experience with the little brown Hydra. At one of our Fish Farms the small-mouth bass spawning stalls were used to culture water fleas after the bass had finished spawning in 1932, and fertilizers were added for this purpose. In the spring of 1933 the bass spawned repeatedly, and within a few days after spawning the males aban-

doned their nests and within another day or two whole beds of eggs simply disappeared. In the stalls where this occurred the area where the bed of eggs had been found to be alive with Hydra.

Only two schools of fry were obtained from beds within the stalls and an examination of these two stalls revealed no Hydra in them. The bass finally quit spawning within the stalls where the water is 18 inches deep and spawned later at large out in the pond. The wild beds which yielded the most fry were the deeper beds, made in water of three to four feet, and stones removed from these beds showed no special abundance of Hydra.

Stones bearing many Hydra were placed in shallow containers and bass eggs and newly-hatched bass fry were added. The fry appeared to be irritated whenever they came in proximity to the Hydra, but none were disabled by the stinging cells or caught by tentacles. No attacks were made upon the eggs, and my only suggestion as to what may have happened to them arises from the fact that Hydra were found attached to the eggs on the beds, and it seems possible that the egg membranes may be ruptured by the suction of the basal attachment.

Numerous large water-fleas (Daphnia magna) were placed in the containers with the Hydra, and a Hydra was seen to catch and kill one of them, although attempts at ingestion failed because of its large size, and it was dropped presently from the tentacles.

These observations may throw some light on the questions raised by W. A. Clemens (1922, p. 446) as to the possible effects of the abundant Hydra in Lake Erie on young fish and their food supply.

There are usually some young bass that escape from the beds in the breeder ponds, and these are not preyed upon by the adults until about August 1st, when they are from 3 to 4½ inches long, another indication of the importance of size of food particles in determining the choice of food by bass, as shown by Turner & Kraatz, (1920, p. 380).

The practice of counting the small-mouth bass fry into the rearing ponds and of actually counting the fingerling bass removed was instituted in 1932, and the data on survival ratio is accurate. The proportion of fry that attain fingerling size differs in the many ponds, but it ranges from 7 to 63 per cent and we have some evidence which indicates that the main losses occur during the first four weeks in the rearing ponds. The cause for this loss is probably an insufficient food supply and the remedy to be applied consists of increasing the abundance of early natural food by the use of fertilizers and supplemental Daphnid cultures. The rearing ponds were fertilized last spring with sheep manure, super-phosphate, and bonemeal, and besides aiding in the production of entomostracans, it led to the development of a heavy mat of algae, mostly Oedogonium and Cladophora. This mat developed along a ten-foot strip along shore, directly over the shoals that had been

fertilized, and its absence from similar shoals in the breeding ponds, where fertilizers were not used, further implicates the fertilizers in its development.

As the fry grow, their demands are for larger and larger particles of food, and when they reach the state when they want larger objects than the largest water fleas, we start offering them finely ground fish. Small-mouth bass young transferred on the day they rose from the beds to previously fertilized rearing ponds, fed on entomostracans until their sixteenth to twenty-first day, then they began taking ground fresh fish. Some ponds of bass required no coaxing, but started taking ground fish as soon as it was offered to them.

Some of the small-mouth bass fry in the rearing ponds have to be coaxed into taking the artificial food, and this is done in one of three ways, in the current at the overflows, where the food is agitated into movement, by hand agitation elsewhere around the pond, and by using what we now call "teacher-sticks," a short pole with a piece of frayed cloth on one end. The cloth is first dipped in the moist food and then dragged slowly through the water. As it moves it makes a little current and the rag flutters in the current, attracting the fish. Also, as it moves, the food sifts out of the cloth, and the bass begin to eat ground fish. They are started on fish ground twice through a grinder plate with one-eighth inch holes, and by August 1st their food is ground once through three-eighth inch holes.

In ponds 11 and 14, at Newtown, in 1933, the small-mouth bass fry started feeding June 5, and for a period of two weeks each day they consumed more food than they had consumed the day before. During this early period the fish eat almost constantly, but as they grow larger they take larger particles of food, and eat at greater intervals. June 20 marked the beginning of a period wherein the maxima of food consumption were attained on every other day, with lessened consumption on alternate days. Beginning July 12 the intervals were widened to three days, and beginning August 6 the intervals were stepped up to four days. The difference between the peaks and valleys is but little at first, but with the widening of the period from two to three and four days the peaks and depressions grow more pronounced. This expresses a tendency rather than a rule and there are numerous decided deviations from this tendency.

The way a bass takes its food changes with its growth and development. When its yolk sac has been absorbed and it begins feeding on the small crustaceans it does so by simply remaining poised in mid-water, moving forward and snapping up the small morsels. Later, instead of merely snapping, the bass makes a rush and hits its prey, describing a very sharp curve and dashing back out of the field of action at an acute angle to that at which it entered.

This type of attack is evolved at about the time the young bass begins to feed upon aerial insects, and may be due to the greater ability of larger prey to resist seizure or to escape. Successful artificial feeding in shallow ponds utilizes this tendency of bass to hit a moving object when it reaches the surface of the water, and the feeder casts the ground food vigorously with an underhand throw that makes the food scatter and skip over the surface of the pond. It is axiomatic that the harder the food hits the water the harder the bass hits the food.

The young bass learn to associate the presence of the man who feeds them with the coming of food, and the presence of the man on the levee is sufficient to attract the fish to his vicinity. By standing still he can feed the group that has gathered, and by feeding while standing at various points around the pond he can feed fairly well, but different size groups develop at the various feeding points. Also we have found that if the feeder moves slowly as he casts the food, the fish will follow and actually consume more food than when fed the other way. Moreover, by encircling the pond always in the same direction, feeding can be more successfully accomplished, as the fish seem to follow better. High levees possess the advantage over low ones that the feeder makes a better target for fish vision.

Most of the fish are feeding well by mid-July and by that time the nights are usually quite hot in Ohio. The night time is the longest period the fish have to go without food and the morning feeding is the heaviest of the day. We have found it expedient to either have some food prepared the night before or to have one man start his day at about 5 A. M. preparing food. When the nights begin to cool, the surface waters are chilled and the fish do not rise to feed well early in the morning. It may even happen that the warmth of the late afternoon sun is necessary to stimulate their hunger, and then their best feeding may be at about seven o'clock, just before sunset.

There are a few spring-fed ponds in the system which are too cold to produce bass to advantage, as the fish use their energy for activity rather than growth. The end ponds at the Xenia hatchery yielded smaller fish than the middle ponds and yet they required from two to three times as much food per pound of fish. The relative temperatures of these ponds as shown by a typical reading, together with the production of the series in 1932, as shown in the accompanying table, reveals a correlation that suggests a high amount of dependence of small-mouth bass upon warmth for feeding and growth. The productivity apparently was determined as much by survival percentage as by food consumption and growth, and it appears probable that the low temperatures were not favorable to the production of entomostracans and that the loss occurred mainly during the early feeding stages.

TABLE 1

	Temp. Surf.	Temp. Bot.	No. of Fry	No. of Fing.	Av. Wt.	Surv. %	Lbs. Fing.	Lbs. Food	Lbs. food per lb. bass
Pond No. 1	65.5	56.5	12,000	2,243	9 oz.	18.7	126	1,511	12
Pond No. 2	75.0	69.0	12,000	5,304	1.57 oz.	44.2	520	3,683	7.1
Pond No. 3	72.5	71.0	12,000	5,743	1.73 oz.	47.8	634	3,793	6.0
Pond No. 4	73.5	65.5	12,000	3,542	1.73 oz.	27.8	385	2,397	6.2
Pond No. 5	72.0	64.5	Record not included because of mid-summer mortality.						
Pond No. 6	68.0	55	12,000	2,483	.60 oz.	20.7	93	1,527	16.4

This year, a simple but effective manner of increasing the productivity of a deep cold pond has been utilized at Xenia. It consists merely of a pipe (down-spouting) installed by the penstock to take the overflow water from the bottom of the pond instead of from the top. In the spring ponds at Xenia the water comes in the bottom of the pond and there is a difference in mid-summer of nine degrees Fahrenheit between top and bottom in pond number one. By taking the overflow water from the bottom the warmer surface waters remain undisturbed, and the fish remain usually in the upper zone, feeding better and growing faster.

The precipitation of calcium carbonate occurred in one of the fish ponds at Xenia in 1932 and interfered with the feeding of the bass, and the phenomenon of marl formation in this case had practical significance. There was but little rooted vegetation, but the pond became quite brownish in August with a phytoplancton pulse.

Beginning about August 20th the hatchery foreman reported that this pond became suddenly milky each day at about 2 o'clock in the afternoon and remained of this color until some time during the night, when it cleared up. Each morning the pond was colorless, of high transparency, and the fish in it were fed at this time, for they would take no food after the transparency was lost. No fish were lost, and there was no apparent harm done to them by this milkiness.

Just at this time the nights had become cool, and the surface waters were chilled each night, warming each day to a point equal to or slightly exceeding the temperature of the lower waters at about 2 P. M., but remaining cooler until that hour. The fish fed well mornings at first, but as the nights grew cooler and the surface waters were more chilled they refused to rise and feed until about 2 o'clock, when the surface waters had warmed to a point equal to or exceeding by a degree or two the temperature of the waters immediately below. This practically eliminated feeding, for at this time the pond grew milky. On one occasion at least, when the milkiness was coming on and the line of demarkation was sharp, a strong wind arose suddenly at 2.30 P. M., and the surface waters were violently agitated. This caused the milkiness to disappear, and it was two hours later, at 4.30 P. M., when the wind had subsided, that the pond became as milky as usual. The event is

quite sudden, not more than ten to fifteen minutes being required to change the pond from clear to milky.

Starting along the shores the water became whitish. There was for a time a sharp line between white and greenish-brown waters, the white pushing out from the north shore, and paralleling it, and the greenish brown bunching up in the center. Water samples were taken from both sides of the line, and the greenish waters were found to contain an incredible abundance of Ceratium, with a few individual Peridiniums mixed in, while the whitish waters contained a comparative abundance of Peridinium with but a few Ceratiums present.

A sample of the surface water was taken at 11.30 A. M., before the pond had become milky, and this sample was analyzed by the chemists of the State Board of Health. Their report is as follows: Temp., 29° C.; Dissolved oxygen, 12.2; Alkalinity: Total: 248, Monocarbonate; 10; PH: 8.2; KMnO Oxygen Consumed, 9.1. The large amount of dissolved oxygen, 150 per cent saturation, indicates that photosynthesis was actively preceeding. Bright sunshine and clear weather prevailed during the period wherein the phenomenon occurred. Although *Ceratium* and *Peridinium* are classified as Mastigophora, (Ward and Whipple, 1918), they possess chlorophyll and probably were the agents in this case responsible for the photosynthetic activity. Minder (1923) reported a similar phenomenon which was due to a large growth of diatoms, chiefly *Tabellaria fenestrata* and *Fragilaria crotonensis.* In photosynthesis these organisms not only used the free carbon-dioxide in solution, but also the half-bound carbon-dioxide, the second radical of the bicarbonate. This left the normal carbonate which, in suspension, caused the milky color.

By the simple process of draining off the surface six inches, and lowering the pond to that extent, just after noon each day, the phenomenon was avoided, and we were again able to feed the fish in late afternoons. All told, this happened daily for just about a month, and there was a noticeable lime deposit on the bottom of the pond, though unfortunately it was not measured.

Although our wishes may be to the contrary, a considerable amount of rooted vegetation develops in the fish ponds, increasing in volume from spring until the latter part of July, when apparently decomposition begins. This annual event has real significance for it interferes with our system of artificial feeding. As decomposition begins the water becomes stained a reddish brown, quite like the tannin-stained streams of the North, and this is followed by a heavy pulse of phytoplancton. When the clear waters begin to show color they lose their transparency, and the bass become laggard in feeding. With the turbidity of the pulse of phytoplancton they practically quit coming to the surface for food and coincident with the coming of the phytoplancton, or slightly later, the minute cla-

doceran, *Scapholeberis,* becomes abundant. Klugh (1927) has shown that Scapholeberis feeds extensively upon the "palmella forms" of phytoplancton, and this explains the coincident pulses of the two forms in the fish ponds. Klugh has also found that he could culture the "palmella forms" of phytoplancton, in a mixture of Moore's nutrient salt solution and leaf infusion, and that the numbers of algae that developed in his cultures were in direct proportion to the amount of leaf infusion used in his culture medium. Apparently the decomposition of the aquatic plants make the water in the fish ponds a suitable medium for the development of phytoplancton.

The extent to which young small-mouth bass generally feed on the Scapholeberis, is not known to me, but in one of the small-mouth bass ponds (Millersport, Number 9), on July 28, 1933, the two-inch bass were found to be feeding almost exclusively on this form. The bass in this pond started taking the ground fish well and the daily amount of food consumed mounted to 14 pounds on July 5, but instead of continuing to mount, it decreased, and coincident with this decrease the Scapholeberis in the water became very abundant. On July 28 the young fish were observed to be actively feeding on this diminutive form, and the intestinal tract of one contained practically nothing but Scapholeberis. The Daphnids do not become abundant in roily water, but this small black, water flea does, and in the case of this pond, it proved to be an obstacle to the success of artificial feeding. (Langlois, 1932, p. 160).

Successive Daphnia pulses in the fish pond have been observed and recorded and a suggestion as to an explanation of these pulses may be in order. About May 10, 1933, the early pulse of Daphnia had passed its peak in the fish ponds of central Ohio, and the pond surfaces carried veritable scums of epphippia. About three pounds of these eggs were gathered and dried, and a small number of them, after drying four days, were placed in water in a bottle on May 16. Many of these hatched on July 12, and just about this date a fresh pulse of Daphnids began to appear in the bass ponds. It seems probable that this second pulse may be explained by the hatching after this interval of the epphippia formed in mid-May, two months previously.

The beneficial effects of crayfish in bass ponds where the fish are being fed ground fish are becoming increasingly obvious. The crayfish do not roil the pond water until about the middle of June and by that date the entomostracans have served their purpose as food for the bass fry, and the sudden roiliness assists us in changing the fish diet from entomostracans to ground fish. The successful bass ponds of 1932 in Ohio were of two kinds, the narrow shallow ones where clear water prevailed, and from which the rooted vegetation had to be manually removed periodically, and the rectangular deep ponds where crayfish kept the water constantly very turbid and free of vegetation. In the latter type of ponds the fish cannot

be kept under constant observation because of the turbidity, but the turbidity is beneficial in preventing plant growth, (Schneberger and Jewell, 1928, p. 14), and the behavior of the fish is modified to our advantage. In turbid water deep feeding is not practiced, and all fish in the pond watch the surface for food. The fish all feed together on the food that is cast to them, hitting it as it hits the water, and by feeding often and freely, cannibalism is minimized. Such ponds produce very satisfactory crops of bass of either of the common species. The crayfish thrive on the waste or unused food and grow and multiply rapidly. That the bass feed to some extent on the smallest crayfish is evidenced by pond No. 3, at Xenia, from which 63 pounds of very small crayfish were removed by seines on the night of July 17, and on the 18th, the consumption of ground carp increased from 36 to 46 pounds.

Although the crayfish are beneficial they become needlessly numerous, and a crop of them can be removed without detriment to the pond and planted in natural waters as a supplemental food supply. During the season of 1933 we moved in this way over two tons of crayfish, numbering about 400,000 individuals.

There have been several innovations in our system this year which may merit mention. In one pond at the Piqua Farm the young bluegills are being experimentally fed ground carp, and they appear to be the biggest and best young bluegills in the system. They have become habituated to getting their food from the feeder and break water to get to his vicinity when he appears upon the levee.

Rockbass are being reared experimentally in several ways. In five ponds of the large rectangular clear water type with abundant rooted vegetation the breeders were removed by seine after spawning and the young are being reared alone. At another place some young were transferred early to a tank and others were transferred to a small shallow dirt basin, and these two latter batches, fed on ground carp are the best of the lot.

One pond contains four hundred and sixty-one spotted bass which were the biggest and best of the 1932 fish, ranging in length from four and one-half to six inches. To our surprise, many of these one-year olds successfully spawned, and the five-inch males guarded their small beds as vigorously and zealously as older fish.

The persistance with which hybrid sunfish (most of which are males as shown by Hubbs & Hubbs, 1933) guard their beds, operates to the disadvantage of the bluegill sunfish in ponds where such hybrids occur. The hybrids usually are larger than the bluegill breeders and they are exceedingly vigorous in attacks on other adults in the ponds. Moreover, they guard their beds for prolonged periods, extending until late in the season, and their activities keep the other fish nervously excited, a condition not favorable to satisfactory eating and growing. For these reasons, the brood stock is

very carefully culled over in the spring and the obvious hybrids are destroyed.

In March, 1933, the bullhead breeders in the State fish ponds were sorted as to species and this year we have eight ponds of brown bullheads (Ameiurus nebulosus) two ponds of black bullheads (A. melas) and one pond of yellow bullheads (A. natalis), instead of having the species mixed as heretofore. This separation had resulted in the better knowledge of specific details of behavior which will be useful in their propagation hereafter. For instance, the brown bullheads did most of their nesting in burrows in shallow water on the levees or bottom, or in tiles placed against the levees for their use. A few nests were built in fanned-out hollows on the bottom and where these eggs were exposed to direct sunlight the hatch was very poor. The black bullheads in certain ponds where facilities for observation were good, made no burrows, but spawned in eight to eighteen inches of water in bright sunlight. In one of the ponds (No. 5, at Zoar) there were several V-type wooden feeding troughs, and every trough was used for spawning, two of them twice. In fact, only two nests were made outside of the troughs in this pond, and these were made on open bottom in eighteen inches of water. It is planned to place more feeding troughs in the black bullhead ponds another year for their use in spawning as well as for their subsequent use in feeding the schools of young.

The yellow bullheads were placed in a pond in one of the more northerly fish farms in the belief that since it is a more northerly species than the other two it might thrive better in cooler water. In this pond (No. 2 at Chagrin Falls) there were sixty-one adult yellow bullheads placed in the pond as they were assembled from other ponds in March, and from that date to this only one of these fish has been seen once. The pond abounds in crayfish which keep its water roily, and the bullheads apparently stay in the deep water. No signs of spawning on the shoals were seen, and it was not until July 7th that we knew spawning had occurred. On that date young bullheads of an average length of an inch and a half were obtained in seine overcasts for crayfish. Obviously the yellow bullheads spawned in deep water (the pond bottom grades to a depth of five and one-half feet), and obviously also the young yellow bullheads do not ball up in masses like the other two species (particularly A. melas) do. Noteworthy also is the fact that in adjacent ponds the brown bullheads spawned twelve days earlier than the blacks.

TABLE 2

1933 Small-Mouth Bass Spawning Data—Number of Beds and Temperatures

DATE	PIQUA 143 old tame Beds	PIQUA 143 old tame Temp.	BUCYRUS 66 young tame Beds	BUCYRUS 66 young tame Temp.	XENIA 119 old tame Beds	XENIA 110 young tame Beds	XENIA 171 old wild Beds	XENIA Temp.	NEWTOWN 222 old tame Beds	NEWTOWN 200 old wild Beds	NEWTOWN Temp.	LONDON 190 old tame Beds	LONDON 100 old wild Beds	LONDON Temp.
4-30	1	60-66	-	——	-	-	-	——	-	-	——	-	-	——
5-1	6	62-68	-	50-50	21	-	-	60-68	-	-	——	17	-	60-68
5-2	17	64-68	-	48-48	13	3	-	62-68	-	-	——	1	-	62-70
5-3	6	60-64	1	51-52	6	1	-	58-66	-	-		-	-	62-67
5-4	-	54-62	-	53-54	-	-	-	54-60	1	-	52-62	-	-	58-68
5-5	-	56-58	-	54-55	-	1	-	54-60	4	-	53-64	-	-	48-58
5-6	1	57-60	-	55-57	-	-	-	56-58	2	-	54-61	-	-	52-56
5-7	-	58-65	-	57-58	-	-	-	56-64	10	-	54-66	1	-	54-60
5-8	-	60-66	-	56-57	-	4	-	60-64	7	-	57-68	-	-	58-64
5-9	1	60-68	-	56-58	4	-	-	60-64	19	-	54-68	1	-	58-64
5-10	4	60-67	-	56-58	3	-	-	60-64	7	-	62-69	2	-	56-60
5-11	-	60-67	4	56-64	-	-	-	60-64	3	-	64-70	4	-	58-66
5-12	2	63-70	5	62-68	2	-	-	62-66	1	-	67-72	1	-	64-72
5-13	-	66-68	6	65-68	1	-	-	64-66	6	-	69-72	-	-	64-68
5-14	3	64-70	3	65-68	14	-	-	63-68	6	-	68-74	14	5	64-66
5-15	1	64-68	5	64-67	1	-	-	63-66	-	-	66-71	-	11	62-68
5-16	1	63-66	5	60-64	-	-	-	60-64	1	-	64-69	1	27	52-64
5-17	-	62-69	6	60-67	4	-	-	60-66	8	-	64-73	-	6	62-70
5-18	4	64-70	-	64-69	4	3	2	62-69	16	-	67-73	1	3	62-72
5-19	7	68-76	4	66-70	4	7	5	66-69	-	29	70-75	-	-	64-74
5-20	2	68-76	3	69-72	1	-	-	66-72	-	1	71-76	2	-	64-78
5-21	4	71-76	-	68-72	1	1	3	68-72	1	-	73-77	-	-	70-78
5-22	2	69-74	3	68-72	1	-	-	66-71	1	-	71-77	-	-	72-79
5-23	-	68-78	4	69-76	3	2	2	64-72	5	3	71-80	-	1	——
5-24	1	72-80	-	73-76	4	-	2	70-73	13	-	76-82	-	-	70-78
5-25	-	72-80	1	73-80	5	-	2	70-76	9	-	78-83	-	-	68-78
5-26	-	74-80	-	75-79	7	4	5	72-76	-	5	78-83	-	-	72-78
5-27	-	76-81	-	75-77	-	-	1	72-76	-	-	78-82	-	-	72-78
5-28	-	73-79	1	75-78	-	-	3	70-76	-	-	76-81	-	-	——
5-29	-	72-76	-	74-76	4	-	1	70-76	-	-	75-81	-	-	——
5-30	-	72-80	-	72-73	-	-	-	68-74	-	-	73-79	-	-	——
5-31	-	68-85	-	69-72	-	-	-	66-73	-	4	71-78	-	-	——
6-1	-	68-76	-	——	-	-	-	64-73	-	5	70-78	-	-	——
6-2	-	71-80	-	——	-	-	-	65-74	-	13	70-80	-	-	——
6-3	-	76-80	-	——	-	-	-	66-74	2	-	74-81	-	-	——

Literature Cited

1. Clemens, Wilbert A.
1922. Hydra in Lake Erie. Science, N. S. Vol. 55. No. 1426. pp. 445-6. New York.

2. Hubbs,C. L. and Hubbs, L. C.
1933. The Increased Growth, Predominant Maleness, and Apparent Infertility of Hybrid Sunfishes. Papers of the Mich. Acad. Sci. Arts, & Letters, Vol. XVII, 1932.

3. Klugh, A. Brooker
1927. The Ecology, Food Relations, and Culture of Fresh-Water Entomostraca. Trans. Royal Canadian Institute, Vol. 16. pp. 15-98.

4. Langlois, T. H.
1931. The Problem of Efficient Management of Hatcheries Used for the Production of Pond Fishes. Trans. Am. Fish. Soc., Vol. 61, pp. 106-115.

5. Langlois, T. H.
1932. Problems of Pondfish Culture. Trans. Am. Fish. Soc., Vol. 62, pp. 156-166.

6. Minder, Leo
1923. Ueber biogene Entkalking in Zurichsee. Verhandl. Interant. Limnolog. Kongress. Vol. 1; pp. 20-32.

7. Nelson, Thurlow C.
1928. Relation of Spawning of the Oyster to Temperature. Ecology. Vol. IX, No. 2, pp. 145-154.

8. Reighard, Jacob
1905. The Breeding Habits, Development and Propagation of the Black Bass. Bull. Mich. Fish Commission. No. 7. pp. 1-73, Lansing, 1905.

9. Schneberger, Edward, and Jewell, Minna E.
1928. Factors Affecting Pond Fish Production. Bull. No. 9, Kansas Forestry, Fish and Game Commission, pp. 1-14.

10. Turner, C. L. and Kraatz, W. C.
1920. Food of Young Large-mouth Black Bass in Some Ohio Waters. Trans. Am. Fisheries Soc. Vol. 50, pp. 372-380.

11. Ward, H. B. and Whipple, G. C.
1918. Fresh-water Biology. N. Y. pp. 1-1109.

Discussion

MR. LANGLOIS: Next Wednesday, when we will be given a demonstration of bass feeding, you will be given a demonstration of the use of the portable X-ray machine with portable fluoroscope screen, and all of you who wish to do so will have an opportunity of looking through a bass and deciding for yourselves whether it is male or female.

Since I wrote this we had the unpleasant experience of being able positively to count the number of fish in a fish pond at Newtown. This particular pond we had fertilized, using between seventy-five and one hundred pounds of a combination of sheep manure and superphosphate—that was early in the season. The daphnia were very abundant when the fry were placed in the pond, and the survival ration had for this year been increased over what it was last year in the same area. Last year we put in 19,000 fry and took out 5,300 fish; this year we put in 18,000 fry and counted out 10,867 fish.

DR. JUDAY (Wisconsin): I am wondering if Mr. Langlois' difficulty with large aquatic plants in the shallow water could be avoided by adopting a scheme which we have been using for the past two years in fertilizing. Instead of putting the fertilizer into the shallow water we have a buoy with a sunken box in the middle, bore holes in the box, take the box out to the middle of the lake, anchor it, put our fertilizer in there and let the water circulate through. We found that to work very successfully. We kept chemical track of the water and have made regular weekly observations on it; in a lake of thirty-eight acres we found the fertilizer to be distributed very nicely over the lake by the winds and the movement of the water. We did this because if we put the fertilizer on the bottom we lose a certain amount of it—some of it will combine with the bottom mud or sand. By anchoring such a device out in the lake we avoid this loss, and the fertilizer goes into the water very easily. We use superphosphate, which readily passes into solution, and also avoids another difficulty—we put in a supply which lasted over the whole season; one dose of it dissolves out and distributes itself over the lake, and it will last a couple of months without any further attention.

MR. LANGLOIS: That is a good suggestion; I certainly will try it out next year.

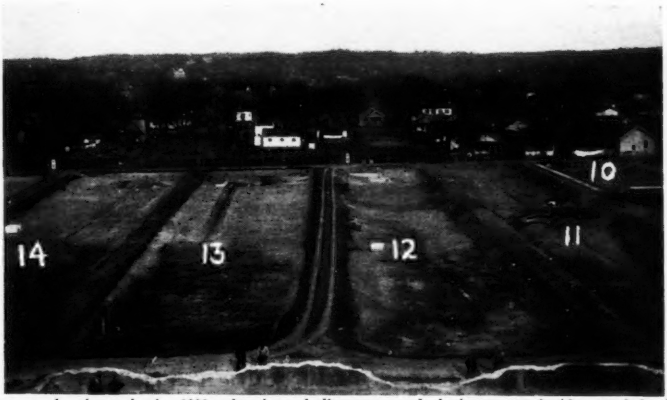
DR. HARKNESS: One of our investigators had a bottle suspended in fifty or sixty feet of water in a depth of over one hundred feet, and when he brought it up he found a hydra attached to the side of the bottle. The engineer who was in charge of the Hamilton, Ontario, water supply told me that during the summer on various occasions he found hydra coming into their pump house from the intake which takes waters from the open water of Lake Ontario. The hydra would come with the water, which is quite unusual to me, and I thought it would be worth mentioning.

DR. GREELEY: How long does it take a female to become completely spawned out?

MR. LANGLOIS: I do not have complete figures on that, Mr. Greeley. There were certainly more than one bed of eggs per female in our spawning area.

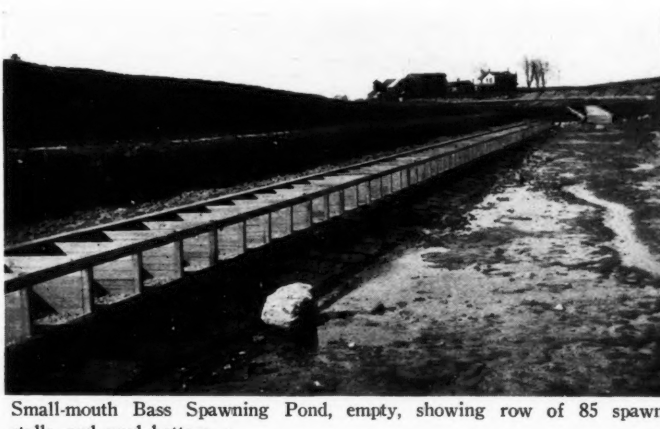
MR. COWDEN (New York): What depth of water do you carry? Have you any current flowing through, or is it stagnant?

MR. LANGLOIS: They have a maximum depth of thirty inches at the lower end, and they are so arranged that the water flows through them.

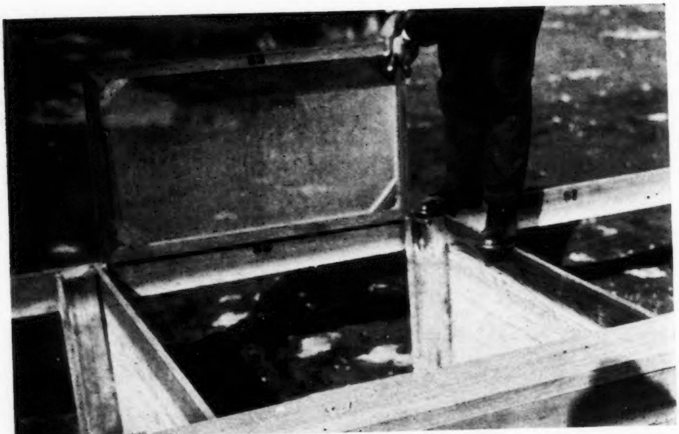


Photograph of ponds in 1933, showing shallowness and drainage to inside catch-basins.

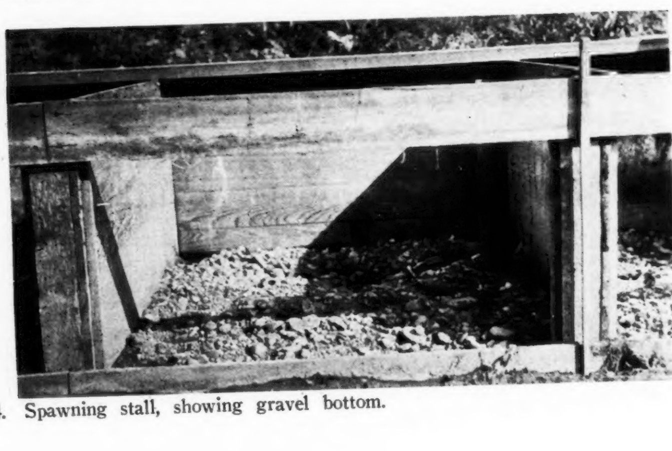
1. Small-mouth Bass Spawning Pond, showing water level maintained above bottom of front board to keep wave action from interfering with vision of nests.



2. Small-mouth Bass Spawning Pond, empty, showing row of 85 spawning stalls, and mud bottom.



3. Spawning stall, showing manner of closing with screen.



4. Spawning stall, showing gravel bottom.

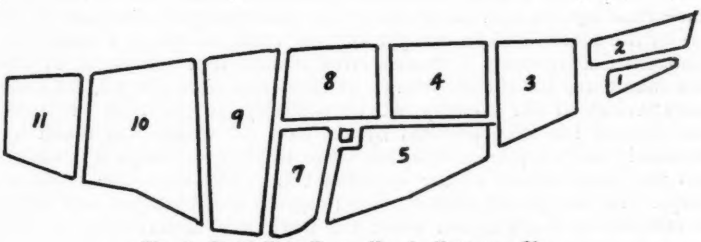


Fig. 1. State Fish Farm, No. 2, Newtown, Ohio
1930. Ground Plan of original large ponds

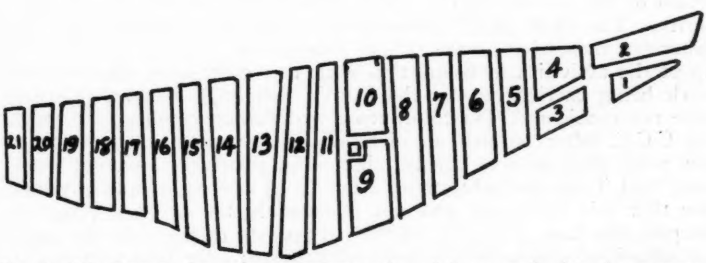


Fig. 2. 1933. Ground plan showing reconstruction of large ponds into long, narrow ponds, better adapted for hand feeding small-mouth bass

C.C.C. STREAM IMPROVEMENT WORK IN MICHIGAN

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University of Michigan, Ann Arbor, Michigan

Introduction

Carl L. Hubbs

The only time I ever inserted a political remark into a talk was some time ago in Indiana when I was addressing the Annual Meeting of the Izaak Walton League of that state, in which I made the comment that it was a fortunate circumstance that whichever of the two candidates for the presidency at that time were elected, the conservationists of the country would probably be satisfied. I think that remark has been justified by the first act which was taken by the newly elected president in his drive to restore prosperity, which was the inauguration of the so-called C.C.C.—Civilian Conservation Corps. The emergency conservation program was then put in charge of officials in Washington, while the work was undertaken, as you know, by the various conservation officials in the several states.

I think most of us here will look upon this work as one of the wisest of the moves that have been taken for the restoration of prosperity. The "fish men," administrators and investigators, and the fishermen themselves, were rather disappointed that in the drawing up of the activities in connection with this emergency conservation work being carried out by the C.C.C., fish improvement questions were not considered. The improvement of fishing conditions through the C.C.C. labor is such an obvious public benefit, since much of this work does involve chiefly labor, with relatively low cost materials, that it was probably more a matter of oversight than anything else that this fish work was not included in the original program. Despite this fact, a number of the enthusiasts throughout the country submitted proposals for work of this sort—for lake and stream improvements, the construction of hatcheries and rearing ponds, and other work which, by making for an increase in the fish population, would lead toward a betterment of fishing conditions. Any projects of this sort which were approved were approved in a qualified way, always with the restriction that only a very small part of the labor in any one C.C.C. camp should be devoted to this work. Finally, and very fortunately from our standpoint, the Emergency Conservation headquarters in Washington formally approved this type of work as one of the legitimate functions of the C.C.C., and from that time on the work has proceeded a little more above board and on a larger scale; and I think it can be prospected for the future on a still larger scale.

This work is expanding very rapidly. In almost every mail word comes in to us referring to new work along the line of lake and

stream improvements being started, generally in connection with the C.C.C. program, from one end of the country to the other. The states in which this is being done are numerous; I can recall offhand either activity or proposals in Connecticut, New Jersey, West Virginia, Michigan, Iowa, Arizona, Pennsylvania, and a considerable number of other states.

In the work with which we are most familiar, that in our own state, a certain organization was built up. The Department of Conservation of our state naturally had charge of the local work in the state, acting as agent for the Emergency Conservation program in this respect. For the lake and stream improvement work, naturally a number of skilled workers were needed to direct and plan and check on the work as it was done. Several of these skilled workers are now busy in our state, having under them a series of construction foremen, one in each camp, directing the work of these boys. Certain of the better workers among the boys, the more intelligent of them, have been placed in charge of squads, and in that way the organization has been carried down to the laborers themselves. The Institute for Fisheries Research, which since its incorporation has taken a very considerable interest in developing this field of lake and stream improvement, had some men available who had had experience along this line, and these men were, in part, taken over by the organization in our state. Two of these young men will briefly tell you something of the work which has been done in Michigan: one, Mr. Tarzwell, representing the stream work, and the other, Mr. Eschmeyer, representing the lake work.

Stream Improvement

Clarence M. Tarzwell

The organization for trout stream improvement work in Michigan has been partly explained by Dr. Hubbs. At present in the stream improvement work we have three skilled workers: Mr. MacClure in charge of the work in the Upper Peninsula; Mr. Johnston in charge of the work on the Pere Marquette River, and myself, in charge of the work in the Lower Peninsula. In each camp there is a foreman having direct charge of the crew. The crews which have been working vary in number from twelve to forty-four. Before any work is undertaken on the streams a preliminary survey is made, which includes the taking of temperatures, a study of the spring feeders, a study of the food supply, a list of the number of sand banks in which erosion has to be prevented, a study of the present trout population, a study of pools and shelter. Trout stream improvement is needed where shelter and pools are insufficient in number, or where food conditions are poor, and this may require improvement

either on part of the stream or on the whole of it. In former years sufficient studies have been made so that it is known how to produce more food in given areas, and it is also known what each area will do and how certain conditions can be produced.

The actual construction work is carried on by the C.C.C. boards. Before any work can be done the material must be secured. In the majority of cases where there are not sufficient stones in the bottom of the stream, the material used is wood—tamarack, cedar, pine, jackpine, oak, or hardwoods—whichever is the most readily available and can be secured most easily. Usually the wood is secured from burnt-over areas. In our work on the Sturgeon River the materials were obtained in a hardwood forest on an old burned over area and floated down to the scene of operations.

When sufficient material was cut and piled it was placed in the river and driven down to the scene of operations. Boys were stationed at critical points, such as at turns, to keep the material moving down the stream. When the material arrived at the location of the improvement work, actual construction was begun.

Log drives in Michigan streams widened the streams and made them shallow, therefore there is need for pools and cover. Where a stream section is too wide and it is desirable to make it narrower, this can be done by the introduction of a wing deflector. Food conditions are improved by the wing deflectors, in such rivers as the Sturgeon, a cold stream which is uniformly swift and in which there are very few slow water areas. These slow water areas are produced behind the deflectors and it is here that food production is greatly increased: a muck deposit is produced, and the mayflies become abundant in about a year or two.

The deflectors are built of logs or stones. The current is accelerated on one side and forms a pool, deepening the water and providing places in which the larger trout may stay. Usually they are used at a bend where it is desired to have a pool. In a sand section the deflectors quickly form pools, but in a gravel section the current has to be forced down against the bottom.

The Y-deflector has a double wing, which directs the current downstream for long distances in sand sections, removing the sand and exposing the gravel. This helps food production, as gravel is much more productive than sand. Very few insects live in sand.

In Michigan, many streams are wide, shallow and flat, and have sand bottoms. It is desirable to make such streams narrow, thus accelerating the current, causing the sand to move and exposing the gravel. It is also desirable to confine this sand in a permanent bar so that it does not move about to cover gravel areas and destroy food. This is done by putting brush in behind the deflectors. This brush is fastened down on deadheads already wired. The high water will go over the deflector, but it will be so retarded by the brush that the sand is dropped. Work done in former years has shown

that the bar may be built up above the surface of the water in one year. This has helped to confine the stream to a channel of the type which is most favorable for trout.

It was hoped that plants would grow behind these deflectors, and it has been found that they do grow there. These plant beds greatly increase the food production and give shelter for the young fish. Some plant beds occuping more than two thousand square feet of area have been produced. It is almost unbelievable that such a large bed could be formed by such a small deflector.

In many swift streams there are no suitable places for the young trout. Frequently no side streams enter the main stream to provide the desired nurseries for young trout. These nurseries can be produced by building a wing deflector and chinking it tightly to keep all water from passing through, so that quiet water is produced below, where muck is deposited and food for young trout is produced. Brush fastened along on top of the deflector and allowed to float out on the downstream side provides a real nursery for young trout in places where it did not exist before. Fish have been noted in great numbers around these nurseries.

Cover is also of great importance in many of our streams. Many Michigan streams are so open, although they do possess some pools, that few trout will stay in them. In such streams much can be done by the introduction of cover alone.

An effort is made to make these covers look as natural as possible. It has been difficult to make some of the boys who were brought up in the city and had never seen a trout stream know how to go ahead with the building of a cover which would have the appearance of being natural. Wires are concealed wherever possible, or their use avoided by wedging.

Where the bottom is so hard that pools cannot be formed by other methods, pools can be formed by low dams. Care has been taken to leave a spillway on top of the dam. Each of the rocks is so placed that the current will not wash it over the top. If these dams are of any depth at all, the pool above is greatly improved by additional cover. The trout find refuge here from floods.

In Michigan there are many high sand banks which erode and add sand to our streams. Sand is very unproductive of food and it is one of the evils that needs to be combatted in Michigan. Perhaps it is the most destructive factor in our trout streams. The importance of the sand erosion has been recognized in the state. The Pere Marquette project, carried on from one of the camps, is primarily for the prevention of erosion. Every year immense quantities of sand have been added to the stream, covering up the gravel areas and cutting down the food production; also filling the pools and making wide, flat, shallow areas which are virtually deserts, in which few fish will stay. These sands banks are being controlled in a number of ways. A deflector placed at the upper end draws the

current away from the bank and thus prevents the eroding action of water at the base. On steep banks brush is fastened and allowed to hang down, holding the sand and giving the plants a chance to grow and to recapture the bank. Terracing is also practiced.

The work this summer (1933) has been limited by the fact that the Michigan Emergency Conservation Work was an immense undertaking, and the tools and materials could not be secured as promptly as was wished. The work was late in getting underway, but it did get underway and much has been accomplished. However, it is hoped that much more will be accomplished next year, since the work has been officially recognized. Plans are being made for work this winter, and also for next year. Plans for the work in the winter camps include the placing of material at suitable locations along the banks before the ground freezes. When the snow comes it is hoped that men will be able to go into the swamps and cut dead timber for the deflectors, cedar for the covers and tamarack for the stakes. Then when the frost comes out of the ground in the spring it is hoped that crews will be put on these large sand banks to do work to prevent erosion. This program will be carried on until June. After June the actual summer work can begin, as the streams will then become warm enough so that the men can work in them during the day. The work of installing cover and deflectors to bring about improved food conditions and more pools and afford cover for fish can be undertaken with material brought out and piled along the stream bank during the winter.

Lake Improvement

R. W. Eschmeyer

After a rather brief experimental period in lake improvement, the Institute for Fisheries Research was given an opportunity to put into practice some of the improvements with which it had been experimenting. This opportunity came through the establishing, by the President, of the Civilian Conservation Corps.

Since our improvement experiments had been in progress for only three years, no improvements were attempted except those which had given definite indication of being beneficial to fish life or to fishing. The work was limited to those environmental changes which called for a minimum amount of equipment and a maximum amount of labor.

Personnel

Two types of men were included in the camps: two of the crews were composed entirely of veterans; the other four included boys (18 to 25 years of age), together with a small number of local woodsmen.

The boys were, for the most part, from the cities and had had no previous training in any phase of the work, not even in such simple matters as cutting brush. They exhibited a desire to learn, however, and with a little patience on the part of the foremen, the crews soon developed into rather efficient units. In almost all camps volunteers were called for and, as a result, the boys in the crew were those who had expressed a desire to work in the water.

The veterans were more experienced, were more steady workers, and were able to accomplish more than the boys, each using the same amount of energy. Almost all of the veterans were past the age, however, when being in the water has a strong appeal, and their work had to be done chiefly from boats. This proved to be somewhat of a handicap.

All things considered, it appears that boys are preferable to older men in work of this kind during the summer. The older men would probably accomplish more when working through the ice in winter.

Types of Improvements Installed

1. Brush shelters.—A large percentage of the time was spent in making and installing various types of brush shelters. These were intended primarily for the protection of young fish. Previous experimental work had indicated that they serve the purpose well. Incidentally, adult fish are also concentrated and better fishing results. If a fairly large number of shelters are installed in a lake, there appears to be relatively little danger of removing too many adult fish, in spite of the tendency to concentrate them around the shelters. The increased protection of young fish is regarded as balancing the increased crop of fish harvested.

2. Gravel for spawning.—Where smallmouth bass occur, and where there is little or no gravel, spawning conditions for this species (and to a lesser degree other species) were improved by providing gravel at proper depth. On hard bottoms the gravel was placed on the bottom in heaps of about a bushel each. In soft-bottomed lakes the gravel was placed in boxes made of old lumber. These boxes were made about three feet square and six inches high, were filled with gravel and then placed on the bottom at proper depth.

3. Slabs for minnow spawning.—In lakes which showed a food deficiency, efforts were made to increase the minnow supply, both by introducing more minnows and by providing slabs for their spawning. The slabs were provided primarily for the blunt-nosed minnows, a species which is excellent as a forage fish, and which spawns on the under surface of objects lying on or near the bottom. Several types of slab devices were used.

4. Aquatic vegetation.—Vegetation, including pond-lilies, musk-grass and several species of pond-weeds, was transferred from lakes containing an abundance of weeds to lakes in which a definite lack of vegetation was in evidence.

5. Minnows and young bass.—Both minnows and bass were planted in several lakes. These were taken from lakes containing an abundance of minnows or bass and were transported in regular hatchery cans to other lakes. They were planted only in lakes where few or none occurred previously.

Since it is probable that a bulletin on lake improvement may be forthcoming in the near future, methods of installing the several improvements need not be discussed here.

Blanks were filled out by the foremen each day indicating the man-hours worked, the number and kind of improvement structures completed, the kind of material used, and certain other significant items. Charts were made to indicate the location of the improvements. The sheets showed the amount of time required to make the several improvement devices, while the charts made it possible to revisit the improvement areas to determine the stability of the several structures, as well as to determine their effect on their environment and on the fish production.

Work Accomplished

The following summary indicates the amount of work which was accomplished during the summer of 1933:

Total number of crews—6.

Total man hours—10,302.

Total lakes improved—28.

Total brush shelters (various types)—1,084.

Total bass nests (boxes)—50.

Total bass nests without boxes—198 (plus 11 cubic yards of gravel).

Total minnow slab devices—233.

Total vegetation planted—55 cans plus 5 truck loads.

Total minnows and yearling bass planted—37 10-gallon cans.

Plans are now in progress for a continuation and expansion of this lake improvement work in Michigan over the winter and next year.

Discussion

Mr. Wickliff: Have you determined the maximum velocity of the current in your best trout waters? How great a velocity of water can a trout stand?

Mr. Tarzwell: I cannot say we know the maximum velocity, but it is my experience that food production is increased as velocity is increased in gravel areas. While trout feed in swift water, they prefer the quieter sections in which to stay, so that they do not have to be continually battling the current in order to maintain their position. Covers are built to give these resting places, while deflectors are used to produce swift water and make food channels. The fish lie in the quiet shelter under the cover,

moving out a short distance to feed in the channel which flows by the cover from the deflector. Trout do not generally rest in water of a velocity greater than two feet per second, but will feed in water having a velocity as great as five feet per second.

MR. ADAMS: Do you believe the stream improvements you have put in will stand the action of the ice next winter?

MR. TARZWELL: This is really not a new thing; we have been doing work in stream improvement for the past four years. The first structures were installed in 1930, the work being under the direction of the Institute of Fisheries Research, which is carrying on scientific research for the Department of Conservation. The Department of Conservation made a special appropriation in 1930 to do some work on the Little Manistee River. As this was really an experimental project, and was the first work of the kind we had done, we knew very little about how to proceed, or how the work was going to stand up. But we built several different types of barriers, and they have been tested. The next year the work was undertaken more in earnest. Many of the first year's installations were lost. In 1931 four or five were lost—one of them was made of stumps, which are very hard to hold. In the winter of 1931 the weather was mild, and there was very little ice. Last year there was much ice, and the deflectors stood very well, but the ice pulled the stakes on some of the covers, which were large,—in fact, too large. In the work on the Sturgeon this year the covers were placed entirely under water, the stakes being sawed off under water; so that in the winter the ice will have no chance to damage it. On the Pigeon River the losses have been small; out of five or six hundred actually built in the seasons of 1931 and 1932, only about a dozen have been lost. These streams are, you might say, warm in summer and cold in winter; the Pigeon freezes so hard you can skate on it, but on the whole the structures remained in place very well. Some of them have been in place for three years, but they were not all built by the C.C.C.

MR. ADAMS: Is this improvement work done on streams the land on either side of which is owned by the state?

MR. TARZWELL: Improvements have been largely confined to state-owned lands, except where, in some cases, work has been done for private people at their own expense; they paid the Institute for the services of the man who was directing the work. The C.C.C. work has been conducted on state-owned streams except where, as along the Sturgeon River, the owners petitioned the Department to do the work. Mr. Westerman can explain that to you more fully.

MR. WESTERMAN: With regard to the employment of E.C.W. workers on privately owned land, the Department has prepared a petition form which is made available to owners who desire to avail themselves of that type of work. This, of course, is relatively new as yet; as Mr. Tarzwell has explained, most of the work this summer has been on state-owned land, but in the hope and expectation that E.C.W. labor will be available for the next twelve months—we do not know definitely yet—we have set up this machinery—a petition form and a letter to accompany it to all inquiring

parties. I have one in my room—I will bring it down so that you may see it later. We expect to consider these in the order in which they are presented, in planning future work.

Mr. Higgins (Washington, D. C.): This is a different type of lake improvement from the type of work carried out by the Conservation Board under the direction of one of the investigators of the Bureau of Fisheries in South Carolina. At the request of the Governor's office, one of the Bureau investigators, Dr. Ellis, made a study of a lake about eighteen miles from Columbia. It is a hydro-electric reservoir created about 1929, which is about thirty-five miles long, with a tortuous shore line comprising some five hundred miles. Fishing in such a reservoir, as in most artificial reservoirs, rises to a very high level in the first two or three years, due, of course, to an abundance of food supply in the newly flooded area. But the fishing in this lake began to fall off very seriously last year, and this year it is still worse. The lake drains from its northern side a great area of clay hills in South Carolina, and the water entering the lake is extremely acid. The lake on the north side is very turbid and the water very acid, with a high carbon dioxide content. The southern shore of the lake, however, is sandy; the fish conditions are more favorable along the southern shore. The improvement project, then, is limited to the southern shore of the lake. In addition to the acid condition of the water, a significant factor in the fish production is the extreme fluctuation in water level. As is common with reservoirs, peak power demand brings down the water level, in this case very severely—it fluctuates as much as sixty-five feet, which of course, is a very extreme condition. The improvement, then, consists in establishing along the southern shore, where water conditions are favorable, a number of sill dams just below the maximum level of the lake, that will retain the water level at a certain minimum as the lake falls. In these areas, which in some cases are as much as a mile long and a quarter of a mile wide, aquatic vegetation will be planted in the narrow fingers or bays; the shore line will be improved by methods such as Dr. Hubbs has described, and it is anticipated that in these bays or impounded areas fishing conditions can be very materially improved. It is excellent water for bass and other warm water fishes, and by stocking these impounded areas with brood fish—and if necessary, by the way, gizzard shad—excellent fishing should be established. A camp has been established on the southern shore of the lake, and under the direction of Dr. Ellis from the biological side, and a skilled engineer, these sill dams will be built. The largest ones will be perhaps three hundred yards long and as much as twelve feet high, but most of them will be smaller and can be handled with trucks from the highway department. It is another case of lake improvement which is of particular significance in connection with the many hydro-electric reservoirs throughout the country in the south.

Dr. Hubbs: I call to mind another type of lake improvement which is of tremendous importance. Throughout the prairie regions of our country the best type of lake improvement is the making of lakes where they

do not already exist. In the Iowa work, with which we have been connected in a consulting way, the construction of artificial lakes takes a very prominent part. It is hoped that the game and fish production of that state can be very materially increased by the construction of a considerable number of large artificial lakes. The wonderful fishing in some of these lakes is an indication of what may be expected there. Before a large lake was artificially constructed, survey lines were run around the shore to show how deep the water would be at each spot, and improvements of various sorts were placed while the men worked on dry land. The material used was cut from the land which was acquired for the purposes of the lake. Along the shores long rows of submarine bulkheads were constructed, about which vegetation could be planted if it would not naturally produce itself there; the wind exposure might be so great that weed beds would not become established without some such protection.

Mr. Farley: You may be interested in a different variety of this same general program. The streams of California come dashing down from ten or twelve thousand feet, and in the course of two or three hundred miles reach their level, so that stream improvement in that state is not the same problem that you have in the Middle West. Back in the high Sierras, in our granite country, we have many small lakes that come out through very narrow niches in the rocks, and frequently a dam no longer than fifteen feet can be built up and thus raise a considerable body of water with very little effort. Some of these areas are utterly devoid of trees, so it is impossible to build a log type dam; the work has to be done with cement and other supplies brought in by pack animals. Work of this kind was done three years ago, first as a cooperative project with the State Fish and Game Commission, the city of San Francisco, on whose watershed we were working, and the county which was involved. Five dams were originally built; they were checked the two years following and were found so satisfactory that this year surveys have already been made for future work. Incidentally, California water supplies and watersheds are so carefully guarded that no work can be done unless a very thorough survey has first been made, and frequently there are insurmountable objections to impounding any water on the watersheds used exclusively for irrigation purposes. But this year an extension camp has been established; just before I left they had completed one additional camp and were starting on the second, and unless they get snowed out, before I get back they will have work proceeding on three during this season. It is an entirely different type of work, adaptable only to mountain country; it is really a variation of the kind of thing in stream improvement that has been spoken of here.

Dr. Van Oosten: I do not know very much about planting brush in the lakes, but the question has occurred to me whether ultimately the predators will find these places of refuge for the small fish, gather around these brush heaps, and deplete the fish supply of the lake perhaps more rapidly than if

the brush heap were not there. Is there any possibility of such a good beginning ending ultimately in disaster from this cause?

Mr. Eschmeyer: Following upon the work we have done this summer, we have been told by some of the old timers that fishing was better than it ever had been. I do not know anything better that could happen to an adult fish than for it to be caught. I do not think it will end in disaster; we have put in so many shelters that I am sure there will be enough surviving for another year.

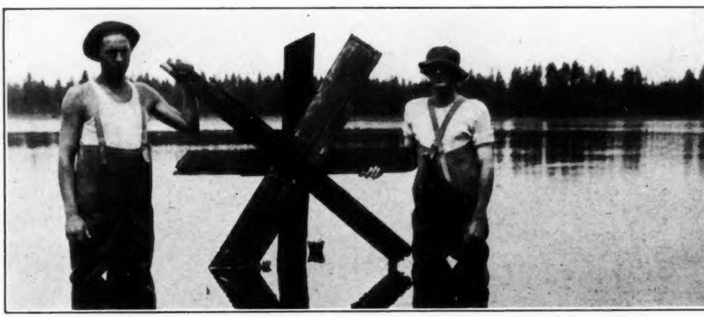
Mr. Markus: With reefrence to the improvement in streams along private properties, I would like to ask Mr. Westerman if he had any difficulty with some of these people who might not have wanted the stream improvement to be made; and also if there was any chance, in the construction of these improvements, of raising the water to a higher stage and causing complaint on the part of those opposed to the work.

Mr. Westerman: Answering the first part of your question, I may say that no attempt has been made to do work unless there has been a request for it; the department simply provides the machinery so that those who wish to have work done may request the department to do it, the purpose being to have a uniform method of getting the information assembled.

To answer the second part of your question, I would say that the mechanics of stream improvement, as we understand it in Michigan, does not involve the building of dams in the ordinary sense of the term; they are rather low head dams in stretches of swift water, and the effect of their construction is not to overflow the land. In fact, our problem is more with dams created through other causes, such as the operations of beaver. The beaver problem is quite an important one on many of the Michigan streams. Beaver have been protected for a good many years; only in the last two or three years has there been any open season on them, and that was a short one. Of course, in many cases there have been reports of nuisance beaver and these have been live trapped and removed to other areas where there may have been requests for beaver and where the Game Commission believe the beaver may be an advantage. The operations of the beaver have brought about what we consider a rather serious problem in relation to the trout in such streams. We hope in a year or two to have more definite information on that question for the Society through the Institute for Fisheries Research, which is tackling the problem for us.

The President: It is evident that this subject of lake and stream improvement is a very complicated one, and an immense amount of experimental work will be required before we shall be in a position to determine the most efficient methods to use under various sets of conditions. It is very evident that the methods which under one set of conditions may be very satisfactory, under a different set of conditions might easily do more harm than good. The whole subject should be investigated at the first opportunity.

1. Towing brush shelter to deeper water. Shelters are usually towed with outboard motor and submerged in water about 10 feet deep.



2. Minnow spawning device. This type made of boards.

3. Minnow spawning device. This type is made of slabs.


4. Placing gravel on firm bottom for bass spawning.


5. Box of old boards filled with gravel. Used where bottom is soft.

APPENDIX

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AMERICAN FISHERIES SOCIETY

Organized 1870

Certificate of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)
Theodore Gill	(Seal)
William E. Meehan	(Seal)
Theodore S. Palmer	(Seal)
Bertrand H. Roberts	(Seal)
Hugh M. Smith	(Seal)
Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

(As amended to date)

ARTICLE I

Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

ARTICLE II

Membership

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) dollars per year.

State Memberships.—Any State, Provincial or Federal Department of the United States, Canada or Mexico may, upon application and the payment of one year's dues become a State member of this Society. The annual dues for State memberships shall be ten ($10.00) dollars per year.

Life Memberships.—Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members provided that no member shall be so transferred unless he shall make request for such transfer and shall have paid dues as an active member of the Society for at least twenty-five years.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several States and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

Election of Members Between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club memberships. A majority of such committee shall decide upon the acceptance of such applications.

Voting.—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a President and a Vice-President, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named, shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-Presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the annual and all special

meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

ARTICLE V

Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

ARTICLE VI

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers:
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-Presidents of Divisions.
   e. Standing Committees.
5. Committees appointed by the President:
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussions of same.
   (*Note*—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

ARTICLE VII

Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.
'06 Perrier, Prof. Edmond, Director, Museum of Natural History, Paris, France.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15, Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif.
'15 Burpee and Letson, Ltd., South Bellingham, Wash.
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.

'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Clinch, C. G. & Co., Inc., 144 Davis St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co. (C. W. Weld, Mgr.), 301 Brannon St., San Francisco, Calif.
'15 Dodge, Sweeney & Co., 36-48 Spear St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3rd St., San Francisco, Calif.
'15 Hendry, C. J., Co., 46 Clay St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The (W. A. Barbour, Mgr.), 443 Mission St., San Francisco, Calif.
'15 Mattlage, Chas. F., Company, 335 Greenwich St., New York, N. Y.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Nauman, C., & Co., 501-3 Sansome St., San Francisco, Calif.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Phillips Sheet and Tin Plate Co., Weirton, W. Va.
'15 Pope and Talbot, Foot of 3rd St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California (W. D. Rigdon, Mgr.), 50-60 Fremont St., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wisconsin.
'25 Bradford, W. A., 14 Wall St., New York, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'03 Casselman, E. S., 508 West Washington St., Sandusky, Ohio.
'11 Cleveland, W. B., Burton, Ohio.
'00 Corliss, C. G., U. S. Bureau of Fisheries, Gloucester, Mass.
'01 Dean, Herbert D., Northville, Mich.
'00 Dunlap, Irving H., U. S. Bureau of Fisheries, Washington, D. C.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'10 Gardner, Mrs. Charles C., The Cliffs, Newport, R. I.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Altadena, Calif.
'28 Hall, W. A. Co., Gardiner, Mont.
'26 Haynes, W. de F., 49 Park Ave., New York, N. Y.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd-Smith, Wilton, 63 Wall St., New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3rd St., Columbus, Ohio
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'17 Pratt, George D., 26 Broadway, New York, N. Y.
'08 Prince, Dr. E. E., Dominion Commissioner of Fisheries, Ottawa, Canada.
'10 Radcliffe, Lewis, 5600 32nd St., N. W., Washington, D. C.
'20 Robertson, Hon. James A. Skerryvore, Holmefield Ave., Clevely's Blackpool, England.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'27 Sheldon, Edward W., 46 Park Ave., New York, N. Y.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina.

'14 Vandergrift, S. H., 1728 New Hampshire Ave., Washington, D. C.
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., University of Illinois, Urbana, Ill.
'13 Wisner, J. Nelson, Institute de Pesca del Uruguay, Punta del Esto, Uruguay.
'05 Wolters, Charles A., Oxford and Marvine Sts., Philadelphia, Pa.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, University of the State of New York, Albany, N. Y.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'31 Agersborg, Dr. H. P. K., Dept. of Fisheries and Game, Concord, N. H.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
'31 Allen, Walter M., U. S. Bureau of Fisheries, La Crosse, Wis.
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'32 Allen, Dr. William S., P. O. Box 7, Sherbrooke, P. Q., Can.
'26 Alm, Dr. Gunnar, Commissioner of Fresh Water Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'23 Amsler, Guy, Department of Fish and Game, Little Rock, Ark.
'33 Anderson, Albin, State Fish Hatchery, Glenwood, Minn.
'08 Anderson, August J., Box 704, Marquette, Mich.
'33 Anderson, Wendell A., Woodruff, Wis.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Van Cortland Ave., Ossining, N. Y.
'25 Atherton, Giles, Citizens State Bank, El Dorado, Kansas.
'29 Atkinson, C. J., Fisheries Dept., Ottawa, Ont., Canada.
'01 Babcock, John P., Provincial Fisheries Dept., Victoria, B. C. Canada.
'32 Baer, Harry D., % U. S. Bureau of Fisheries, Hagerman, Idaho.
'32 Bailey, G. E., Dominion Government Fish Hatchery, Twin Butte, Alt., Can.
'32 Bailliere, Lawrence, Stoutland, Mo.
'32 Bajkov, Dr. A., Atlantic Biological Station, St. Andrews, N. B., Can.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'29 Baker, Dr. Davis, Insurance Bldg., Glens Falls, N. Y.
'15 Balch, Howard K., 156 West Austin Ave., Chicago, Ill.
'98 Ball, E. M., 1328 South Kingshighway, St. Louis, Mo.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'20 Barbour, F. K., Linen Thread Co., 200 Hudson St., New York, N. Y.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'26 Barnes, J. Sanford, 52 Vanderbilt Ave., New York, N. Y.
'33 Bauman, Albert J., State Fish Farm No. 4, Russells Point, Ohio.
'28 Beakbane, Alfred Bernard, 31 Thompson Ave., Glens Falls, N. Y.
'00 Beeman, Henry W., New Preston, Conn.

'28 Bell, F. Howard, International Fisheries Commission, University of Washington, Seattle, Wash.
'33 Bell, Frank T., U. S. Bureau of Fisheries, Washington, D. C.
'18 Bellisle, J. A., Inspector General of Fisheries and Game, Quebec, Canada.
'25 Bengard, John P., Valley Ranch, New Mexico.
'13 Berg, George F., 1702 E. 12th St., Indianapolis, Ind.
'27 Biddle, Spencer, R. F. D. No. 1, Vancouver, Wash.
'27 Birdseye, Clarence, General Seafoods Corporation, Gloucester, Mass.
'28 Bishop, M. S., R. F. D. No. 2, Iroquois Trout Hatchery, Glens Falls, N. Y.
'24 Bitzer, Ralph, Montague, Mass.
'24 Blanchard, Charles, State Fish Hatchery, Unionville, Conn.
'25 Blankenship, Dr. E. L., Crystal Springs Trout Farm, Cassville, Mo.
'32 Blosz, John, Lake Park, Ga.
'32 Bogie, Robert R., 6740 Fourth Ave., Brooklyn, N. Y.
'26 Borcea, Dr. Jean, Univ. of Jassy, Jassy, Roumania.
'30 Borger, Garrison, Brookhaven, N. Y.
'25 Borger, Samuel I., Brookhaven, N. Y.
'30 Bosdeck, Ed., State Fish Hatchery, Route 11, Defiance, Ohio.
'25 Bottler, P. G., State Fish Hatchery, Emigrant, Montana.
'00 Bower, Ward T., U. S. Bureau of Fisheries, Washington, D. C.
'30 Bowling, T. C., Pryor, Okla.
'30 Branion, Hugh D., Dept. of Biochemistry, University of Toronto, Toronto, Canada.
'20 Breder, C. M., Jr., New York Aquarium, New York, N. Y.
'26 Brenard, Thomas L., % Martin Fish Co., Atchafalaya, La.
'28 Brittain, William H., % U. S. Bureau of Fisheries, Louisville, Ky.
'16 Brown, Dell, U. S. Bureau of Fisheries, Lonoke, Ark.
'26 Brown, George E., 4508 York Ave., S., Minneapolis, Minn.
'30 Brown, James, Commissioner of Fish and Game, Montpelier, Vt.
'32 Brown, Merrill W., Box 956, Stanford University, Calif.
'28 Brunelli, Gustav, Director del Laboratorio Centrale d'Idrobiologia, Piazza Borghese, 91, Rome, Italy.
'20 Buller, C. R., Pleasant Mount, Wayne County, Pa.
'29 Burke, Dr. Edgar, Jersey City Hospital, Jersey City, N. J.
'17 Burkhart, Joe, Big Rock Creek Trout Club, St. Croix Falls, Wis.
'31 Burr, J. G., Game, Fish and Oyster Commission, Austin, Tex.
'28 Butler, Edward C., Box 125, Allston, Station, Boston, Mass.
'30 Butler, George Edward, Winnipegosia, Man., Canada.
'27 Byers, A. F., 1226 University St., Montreal, Que., Canada.
'27 Cable, Louella E., U. S. Bureau of Fisheries, Washington, D. C.
'32 Carl, Elmer B., 24 Broadway, Hagerstown, Md.
'23 Catt, James, District Inspector of Hatcheries, Customs House, St. John N. B., Canada.
'07 Catte, Eugene, Catte Fish Hatchery, Langdon, Kansas.
'18 Chamberlain, Thomas Knight, 7 Willis Ave., Columbia, Mo.
'32 Chrassin, J. P., Margaree Harbor, N. S., Canada.

'29 Chute, Walter H., Director, John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'32 Clark, Arthur L., State Capitol, Hartford, Conn.
'33 Clark, G. A., State Fisheries Laboratory, Terminal Island, Calif.
'33 Clausen, Ralph G., N. Y. State College of Teachers, Albany, N. Y.
'21 Clemens, Dr. Wilbert A., Pacific Biological Station, Nanaimo, B. C., Canada.
'00 Cobb, Eben W., R. F. D., Farmington, Conn.
'29 Cokeley, H. A., Crawford, Neb.
'04 Coker, Dr. Robert E., Univ. of North Carolina, Chapel Hill, N. C.
'26 Comee, Joseph F., People's Gas Bldg., Chicago, Ill.
'28 Cook, A. B., Jr., Field Supt. of Hatcheries, Ionia, Mich.
'17 Cook, Ward A., U. S. Bureau of Fisheries, Duluth, Minn.
'24 Coolidge, Charles A., 122 Ames Building, Boston, Mass.
'33 Cooper, Gerald P., Museum of Zoology, Univ. of Michigan, Ann Arbor, Mich
'32 Cooper, K. N., Auburndale Gold Fish Co., 1449 Madison St., Chicago, Ill
'33 Coppock, Fred, American Aggregates Corp., Greenville, Ohio.
'33 Corcoran, John P., Pioneer Point Farm, Centreville, Md.
'32 Corder, H. G., Anderson Lake Hatchery, Kildonan P. O., Vancouver, Island, B. C., Canada.
'31 Cotton, Maj. Ray E., Secy., Dept. of Conservation, Lansing, Mich.
'32 Cowden, Sumner M., Conservation Dept., Albany, N. Y.
'30 Craig, Charles, Harrisville, Mich.
'13 Crandall, A. J., Ashaway Line & Twine Mfg. Co., Ashaway, R. I.
'32 Crawford, H. C., Nelson Hatchery, Nelson, B. C., Canada.
'33 Croker, Richard, State Fisheries Laboratory, Terminal Island, Calif.
'28 Crosby, Col. W. W., Box 685, Coronado, Calif.
'30 Crowell, Mary, Shortsville, N. Y.
'08 Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.
'28 Cumings, Ed., % Cumings Brothers, 901 S. Saginaw St., Flint, Mich.
'31 Dauenhauer, J. B., Jr., Courthouse Bldg., New Orleans, La.
'06 Davies, David, U. S. Fisheries Station, Put-in-Bay, Ohio.
'28 Davis, Hosea L., Fisheries Station, Mammoth Springs, Ark.
'23 Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
'26 Day, Harry V., 510 Park Ave., New York, N. Y.
'31 Deake, Standish, Div. Fish and Game, 20 Somerset St., Boston, Mass.
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'27 DeBoer, Marston J., Dept. of Conservation, Lansing, Mich.
'25 De Cozen, Alfred, 1226 Broad St., Newark, N. J.
'28 De Forest, Byron, P. O. Box 971, Great Falls, Mont.
'30 Deibler, O. M., Commissioner of Fisheries, Board of Fish Commissioners, Harrisburg, Pa.
'24 Dence, Wilford A., New York State College of Forestry, Syracuse, N. Y.
'19 Denmead, Talbott, 2830 St. Paul St., Baltimore, Md.
'23 Dennig, Louis E., 3817 Choteau Ave., St. Louis, Mo.
'30 Detwiler, John D., University of Western Ontario, London, Ont., Canada.

'33 Deuel, Charles R., Canton, N. Y.
'30 Devlin, Marie Blanche, Parliament Bldgs., Colonization Dept., Quebec, Can.
'99 Dinsmore, A. H., U. S. Bureau of Fisheries, St. Johnsbury, Vt.
'32 Domogalla, Dr. Bernhard, 803 State St., Madison, Wis.
12 '27 Dorn, C. G. 50 Jackson Ave., Bradford, Pa.
'28 Dunlop, Henry A., International Fisheries Com., University of Washington, Seattle, Wash.
'32 Dwyer, J. N., 371 St. Joseph Blvd., W., Montreal, Canada.
'24 Earle, Swepson, Conservation Dept., 516 Munsey Bldg., Baltimore, Md.
'27 Eaton, Dr. E. H., 678 Main St., Geneva, N. Y.
'32 Eaton, R. H., Pitt Lake Hatchery, Alvin, B. C., Canada.
'32 Eddy, Samuel, Zoological Dept., Univ. of Minnesota, Minneapolis, Minn.
'26 Einarsen, Arthur S., Box 384, Seattle, Wash.
'31 Eisenlohr, George M., U. S. Fisheries Station, La Crosse, Wis.
'32 Ekers, L. A., 1455 Drummond St., Montreal, Canada.
'33 Ellsworth, Robert E., Silver Creek Trout Station, East Tawas, Mich.
'31 Emberson, G. F., De Soto, Wis.
'13 Embody, Dr. George C., Triphammer Road, Ithaca, N. Y.
'21 Emerick, Walter G., R. F. D. 1, Iron Kettle Trout Hatchery, Watervliet, N. Y.
'26 Emmons, H. Nelson, Marion, Mass.
'32 Epps, E. V., Vedder Crossing P. O., B. C., Canada.
'17 Erickson, C. J., P. O. Box 1446, Boston 2, Mass.
'32 Eschmeyer, R. William, University Museums, Ann Arbor, Mich.
'04 Everman, J. W., Supervisor of Public Utilities, Dallas, Texas.
'29 Farley, John L., 450 McAllister St., Fish and Game Commission, San Francisco, Calif.
'32 Farrell, Michael A., Dept. of Bacteriology, Yale Univ., New Haven, Conn.
'32 Faulstich, W., U. S. Bureau of Fisheries, Kodiak, Alaska.
'28 Fearnow, Theodore C., State Fish Hatchery, Ridge, W. Va.
'32 Fellers, Dr. Carl R., Massachusetts State College, Amherst, Mass.
'30 Fentress, Eddie W., U. S. Fisheries, Cape Vincent, N. Y.
'32 Fiedler, R. H., U. S. Bureau of Fisheries, Washington, D. C.
'29 Firth, Frank Edward, U. S. Bureau of Fisheries, Fish Pier, Boston, Mass.
'31 Fish, Frederic F., U. S. Bureau of Fisheries, Washington, D. C.
'33 Fisk, Harry T., Crown Point, N. Y.
'28 Foerster, R. Earle, Pacific Biological Station, Nanaimo, B. C., Canada.
'04 Follett, Richard E., 2134 Dime Bank Bldg., Detroit, Mich.
'32 Forsythe, W. P., Kennedy Lake Hatchery, Tofino, B. C., Canada.
'29 Fortney, Robert, Dept. of Conservation, Lansing, Mich.
'10 Foster, Frederick J., Univ. of Utah, Salt Lake City, Utah.
'24 Frantz, Horace G., Frantzhurst Rainbow Trout Co., 1022 S. Schwatch, Colorado Springs, Colo.
'22 Fraser, Dr. C. McLean, University of British Columbia, Vancouver, B. C., Canada.
'18 Fridenberg, Robert, 22 West 56th St., New York City, N. Y.
'28 Gage, Simon H., Stimson Hall, Ithaca, N. Y.

'24 Gale, R. G., State Fish Hatchery, French River, Minn.
'30 Gantenbein, C. B., Mt. Clemens, Mich.
'18 Garnsey, Leigh, Box 653, Redlands, Calif.
'30 Gibaut, F. M., Dept. of Colonization, Game and Fisheries, Quebec, Can.
'26 Gibbs, George, Pennsylvania Station, New York, N. Y.
'30 Gilbert, Walter B., 103 South First St., Albuquerque, New Mexico.
'29 Gill, G. H., Manchester, Iowa.
'27 Gordon, Seth, Investment Bldg., Washington, D. C.
'33 Goswell, John C., St. Peters, N. S., Can.
'31 Gowanloch, James Nelson, Chief Biologist, Bureau of Research, Dept. of Conservation, New Orleans, La.
'28 Grammes, J. Frank, Grammes Brook Trout Hatchery, 1119 Linden St., Allentown, Pa.
'19 Gray, Stedman H., 2511 Second Ave., West, Seattle, Wash.
'26 Greeley, John R., Museum of Zoology, Ann Arbor, Mich.
'29 Greene, Dr. C. Willard, N. Y. State Conservation Dept., Albany, N. Y.
'31 Grim, D. N., Glen Eyre, Pa.
'31 Guenthner, Jacob, State Fish Hatchery, Piqua, Ohio.
'13 Guerin, Theophile, Lock Drawer 1003, Woonsocket, R. I.
'28 Hale, Robert F., Malone, N. Y.
'26 Halferty, G. P., 600 Coleman Bldg., Seattle, Wash.
'06 Hankinson, Prof. T. L., 96 Oakwood Ave., Ypsilanti, Mich.
'10 Hansen, Ferdinand, Romanoff Caviar Co., Grand Central Palace, 480 Lexington Ave., New York, N. Y.
'25 Hanson, Henry, State Fish Hatchery, Lanesboro, Minn.
'28 Harkness, William J. K., Dept. of Biology, University of Toronto, Toronto, Canada.
'30 Harner, Ernest, State Fish Hatchery, Xenia, Ohio.
'17 Harriman, W. A., 39 Broadway, New York, N. Y.
'32 Harrison, Charles William, Dominion Government Fisheries Office, Winch Bldg., Vancouver, B. C., Canada.
'22 Hart, M. D., Department of Game and Inland Fisheries, Library Bldg., Richmond, Va.
'32 Hartman, Fred B., Park View, N. M.
'31 Haskett, C. H., Bureau of Fisheries, La Crosse, Wis.
'30 Hatton, Daniel G., Supt., Blooming Grove Hunting and Fishing Club, Glen Eyre, Pa.
'33 Hawes, Harry B., Transportation Bldg., Washington, D. C.
'04 Hayford, Charles O., State Fish Hatchery, Hackettstown, N. J.
'28 Hazzard, A. S., 210 Boston Bldg., Salt Lake City, Utah.
'32 Heins, Erwin F., John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'08 Hemingway, E. D., 239 Elbow Lane, Philadelphia, Pa.
'33 Herndon, G. B., 724 Mulberry St., Jefferson City, Mo.
'32 Herrington, William C., Bureau of Fisheries, Biological Institute, Cambridge, Mass.
'23 Hesen, Herman O., Jr., U. S. Fisheries Station, Louisville, Ky.
'32 Higgins, Elmer, U. S. Bureau of Fisheries, Washington, D. C.

'15 Hildebrand, Samuel F., U. S. Bureau of Fisheries, Washington, D. C.
'32 Hile, Dr. Ralph, U. S. Bureau of Fisheries, University Museums, Ann Arbor, Mich.
'33 Hills, Clifford, Wild Rose, Wis.
'08 Hinrichs, Henry, Jr., 7700 Eastlake Terrace, Chicago, Ill.
'23 Hirsheimer, Louis C., 501 North Third St., La Crosse, Wis.
'23 Hogan, Joseph R., State Fisheries, Lonoke, Ark.
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